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USDA/STATE/EPA ASSESSMENT TEAM OF THE
NATIONAL AGRICULTURAL PESTICIDE IMPACT ASSESSMENT PROGRAM
UNITED STATES DEPARTMENT OF AGRICULTURE

THE BIOLOGIC ASSESSMENT
OF THE PESTICIDE
CARBON TETRACHLORIDE

U.S. DEPT. OF AGRICULTURE
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Table of Contents

	Page
I. Title	i
II. Table of Contents	ii
III. Membership of Assessment Team	v
IV. Acknowledgment, Donating Partners	vii
V. Abstract	viii
VI. Introduction	1
A. Purpose of Report	1
B. Brief History of Use of CCl_4	2
C. SPAR Triggers	2
VII. Physical and Chemical Properties of CCl_4	3
A. Physical Properties	3
B. Chemical Properties	4
VIII. Biological and Economic Information	25
A. Stored Grain and Milling Products	25
1. On-Farm Storage	25
2. Off-Farm Storage	28
3. Milling and Processing Plants	31
B. State, Federal, and Foreign Regulations	37
1. Control of Imports to Stored Grain	37
C. Use of CCl_4	50
1. CCl_4 for Fumigation	50
2. Use of CCl_4 in Grain Storage	51
3. Use of CCl_4 in Grain Storage	51
4. Use of CCl_4 in Flour Mills and Processing Plants	53
5. Use of CCl_4 on Export Grain and Milling	57
6. Use of CCl_4 on Imported Commodities	70
7. Relationship of the Annual Agricultural Storage of CCl_4 to On-Farm, Off-Farm, Milling and Processing Plants	71

This Report was prepared jointly by the
 USDA-State-EPA
 Carbon Tetrachloride Assessment Team

Table of Contents

	<u>Page</u>
I. Title	i
II. Table of Contents	ii
III. Membership of Assessment Team	v
IV. Acknowledgement, Non-team Members	vii
V. Abstract	viii
VI. Introduction	1
A. Purpose of Report	1
B. Brief History of Usage of CCl ₄	1
C. RPAR Triggers	2
VII. Physical and Chemical Properties of CCl ₄	5
VIII. ^{ant Pest Loss} Pest Information	6
IX. Biological and Economic Information	25
A. Stored Grain and Milled Products	25
1. On-Farm Storage	25
2. Off-Farm Storage	28
3. Milling and Processing Plants	31
B. State, Federal, and Industry Recommendations for Control of Insects in Stored Grain	37
C. Use of CCl ₄ on Stored Grain and Milled Products	50
1. CCl ₄ Formulators, Formulations, and Costs	50
2. Use of CCl ₄ in On-Farm Grain Storage	54
3. Use of CCl ₄ in Off-Farm Grain Storage	59
4. Use of CCl ₄ in Flour Mills and Processing Plants	63
5. Use of CCl ₄ on Export Grain and Oilseeds	68
6. Use of CCl ₄ on Imported Commodities	70
7. Estimates of the Annual Agricultural Usage of CCl ₄ : On-Farm, Off-Farm, Milling and Processing Plants	71

	<u>Page</u>
D. Alternatives for the Control of Insects in Stored Grain and Milled Products	80
1. Pest Control Materials Currently Registered	80
a. Phosphine	80
b. Methyl Bromide	85
c. Chloropicrin	93
d. Other Organic Compounds Formulated with CCl ₄	95
e. Grain Protectants	95
f. Miscellaneous Materials	96
2. Alternatives to Registered Fumigants and Protectants	97
a. Physical Controls	97
(1) Inert Dusts	97
(2) Heating and Cooling	98
(3) Drying	98
(4) Irradiation and Sonication	99
(5) Hermetic Sealing	99
(6) Cleaning and Sanitation	99
b. Chemical Controls	100
(1) Modified Atmospheres	100
(2) Protectants and Residuals	100
(a) Acephate	101
(b) Bay SRA 7660	101
(c) Chlorpyrifos-methyl	101
(d) Pirimiphos-methyl	101
(e) Diuretic Agents	102
(f) Fenitrothion	102
(g) Iodofenphos	102
(h) Methacrifos	102
(i) Methyl Phoxim	103
(j) Pyrazoline Derivatives	103
(3) Insect Growth Regulators	104
(4) Natural Products	104
(5) Grain Fumigants	105
E. Exposure Hazards	106
X. Reference Cited	113

Table Titles

	<u>Page</u>
Table 1. Alphabetical list of the major and minor insect pests of stored grain.	7
Table 2. Insect species and population densities found in 1977-78 corn and wheat exports.	10
Table 3. Species, percentage incidence, and average density of insects in wheat, corn, and oats stored on the farm.	12
Table 4. Responses from extension personnel in 44 States to the question: Which stored-product insects cause the biggest problems in your State on processed food?	14
Table 5. Carbon tetrachloride fumigant formulations and alternative formulations recommended by States for use on stored grain.	38
Table 6. States recommending the use of a carbon tetrachloride formulation on stored grains.	39
Table 7. Estimated annual use of carbon tetrachloride (CCl ₄) in the formulation of liquid fumigant mixtures.	72
Table 8. Estimated annual use of carbon tetrachloride (CCl ₄)-based liquid fumigants in bulk stored grain.	74
Table 9. Estimated gallonage of fumigant formulated with ethylene dibromide (EDB) and carbon tetrachloride (CCl ₄).	75
Table 10. Estimated annual use of ethylene dibromide (EDB) and carbon tetrachloride (CCl ₄) in mill machinery fumigants.	75
Table 11. Summary of the estimated annual use of carbon tetrachloride (CCl ₄) in the formulation of liquid fumigant mixtures.	76

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V. Abstract

Carbon tetrachloride is widely used as an ingredient of liquid fumigant mixtures for the control of stored grain insects. It is also used as a regulatory treatment at ports of entry for conifer and other seed infested with certain insects. Because it is nonflammable, it reduces the fire hazards associated with the use of other insecticidal fumigant materials, such as carbon disulfide, and aids in their distribution through the treated commodity.

There are three general types of liquid fumigant mixtures containing CCl_4 that are marketed in the United States. Those in which CCl_4 is the major constituent, those in which EDC is the predominant compound, and those composed primarily of EDB. The most widely used liquid fumigant mixture for the treatment of bulk-stored grain and for regulatory use belongs to the first type and consists of an approximate ratio (by volume) of 80 percent CCl_4 to 20 percent CS_2 , commonly known as 80:20.

It is estimated that between 13,500,000 and 20,000,000 pounds of CCl_4 are used annually in liquid fumigant mixtures for treatment of bulk grain and milling machinery. Approximately 400,000,000 bushels of grain are fumigated annually with CCl_4 containing liquid fumigants.

Some 41 insect species are considered to be pests of stored grain (19 major and 22 minor pest species). Most of these insects are found throughout the world where grain is harvested and stored. Insects damage grain directly by feeding on individual kernels and indirectly by contaminating the grain with their feces, webbing, cast skins, and body parts. It is essential that grain in the U.S. marketing system be kept free of insect pests to ensure its acceptance by both domestic and foreign grain buyers.

CCl_4 is not utilized primarily for its insecticidal activity, but is an essential component of several important liquid fumigant mixtures used for the control of stored grain insects, and its loss would have significant economic impact.

VI. Introduction

On October 15, 1980 a notice of rebuttable presumption against registration (RPAR) of pesticidal products containing carbon tetrachloride (CCl_4) was published in the Federal Register (pp. 68534-68550). A notice of RPAR is issued by the Environmental Protection Agency (EPA) when the evidence related to risk meets or exceeds the criteria set forth in 40 CFR 162.11(a)(3) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended. The evidence or basis for the RPAR notice is described in EPA's Position Document-1 (P/D1) which is published in the same issue of the Federal Register (pp. 68551-68584). P/D1 gives evidence that CCl_4 meets or exceeds the risk criteria for RPAR because it has induced oncogenic effects in experimental mammalian species after oral administration (40 CFR 162.11(a)(3)(ii)(A)) and it has produced chronic or delayed toxic effects in test animals and in humans (40 CFR 162.11 (a)(3)(ii)(B)).

A. Purpose of Report

The purpose of this report is to develop biological, exposure, and economic information related to the registered pesticidal uses of CCl_4 so that a proper evaluation of the risks/benefits related to the reregistration of pesticide products containing CCl_4 can be made. This report does not include information on pesticidal or other products that contain CCl_4 as an inert ingredient.

B. Brief History of Usage of CCl_4

Carbon tetrachloride is widely used as an ingredient of liquid fumigant mixtures. Because it is nonflammable, it reduces the fire hazards associated with the use of flammable fumigant materials such as carbon disulfide, and it

also aids in their distribution or penetration through a bulk-grain mass. Most fumigant mixtures containing CCl_4 are produced in the United States, though some are produced and marketed as commodity fumigants in Western Europe. The annual production of CCl_4 in the United States is reported at nearly one billion pounds. About 95 percent of the CCl_4 produced is used in the manufacture of fluorocarbons. The remaining 5 percent is formulated into a variety of products including those of a pesticidal nature. Only 2 percent of production or about 20 million pounds is used in formulating commodity and space fumigants. There is a wide variety of pesticide formulations, including liquid fumigant mixtures that contain some portion of CCl_4 . The most widely used liquid fumigant mixture for the treatment of bulk-stored grain consists of an approximate ratio of 80 percent CCl_4 to 20 percent CS_2 , commonly known as "80:20." These "80:20" formulations contain approximately 10 lb of CCl_4 per gallon. Though CCl_4 is the major constituent of these formulations, it is relatively non-toxic to insects and, therefore, is never marketed as a fumigant per se. CCl_4 as well as some of the other constituents of liquid fumigant mixtures is exempt from the requirement of a tolerance for residues in fumigated commodities. That is, residues can be removed with adequate aeration.

C. RPAR Triggers

Rebuttable presumption against registration of a pesticide is implemented when evidence related to risk meets the criteria set forth in 40 CFR 162.11(a)(3). CCl_4 has been found to exceed certain of these risk criteria which are expressed briefly as follows (Federal Register, 45(201: Oct. 15, 1980):

1. It has induced oncogenic effects in experimental mammalian species (rats, mice, and hamsters). Chronic CCl_4 -induced cirrhosis of the

liver has been observed in these animals after oral, subcutaneous, or inhalation exposure. Chronic exposure of humans has resulted in severe liver damage (79).

2. It has produced chronic or delayed toxic effects in test animals and humans. Chronic administration of CCl_4 to rats has resulted in toxic effects to the kidneys; chronic exposure of humans has resulted in nephrosis and degenerative changes in the nephron (79).
3. The large number of toxicology studies conducted on CCl_4 , reviewed in EPA (119) and NIOSH (79), collectively present evidence that CCl_4 is oncogenic in experimental mammalian species and may be oncogenic in man. EPA summarized the results of studies with mice by saying that it "found carbon tetrachloride to be highly carcinogenic for liver in mice" (119). Also, as cited in NIOSH (79) studies have shown nephrotoxicity in laboratory test animals and in humans resulting from chronic exposure to CCl_4 .
4. There is considerable evidence that both man and animals are exposed continuously to low levels of CCl_4 because it is a contaminant of our daily food, water, and air. The presence of CCl_4 residues in such items as wheat, flour, and bread (19, 53, 123) is presumed to result from pesticidal use. However, residues in such other dietary items as beef, olive oil, potatoes, apples, and pears must result from nonpesticidal use of CCl_4 as there is no approved pesticidal use for CCl_4 on these items.

CCl_4 has been found in concentrations of less than one part per billion (<1 ppb) in samples of water such as rain, snow, surface water, potable water, and in the sea (120).

The occurrence of CCl_4 in air is well documented and cited by EPA (119). It is believed to be primarily of anthropogenic origin. Concentrations range from 0.00078 to 0.00091 mg/m^3 with no major gradients in the global distribution. EPA speculates that "the ubiquitous occurrence of CCl_4 in air could result in contamination of food items and thus be the source of observed carbon tetrachloride residues in food."

The adverse effects, if any, of these levels of CCl_4 contaminants in our food, water, and air have not been determined. However, modern analytical procedures now allow detection of CCl_4 residues as low as 1 ppb. Therefore, in the event that EPA does allow continued registration of CCl_4 , tolerances will be required for all grains, meats, poultry, eggs, and milk for which CCl_4 is registered for use in accordance with sections 406, 408 and 409 of the Federal Food, Drug and Cosmetic Act as amended.

5. Other relevant adverse effects such as the teratogenicity or mutagenicity of CCl_4 have not been adequately or conclusively demonstrated. Therefore, EPA concludes that a data gap exists for teratogenic and mutagenic effects and certain studies may be required if CCl_4 is to remain registered. If the Agency holds to this requirement and the requirement for establishing tolerances for residues on all grains, etc., there is much doubt that CCl_4 will remain registered, if for no other reason than the cost of developing the required informaton.

VII. Physical and Chemical Properties of CCl_4

Carbon tetrachloride is a chlorinated hydrocarbon compound; is a colorless liquid at room temperature; is prepared commercially by the interaction of carbon disulfide and chlorine or by the chlorination of certain hydrocarbons; has a moderately strong ethereal odor similar to that of chloroform; is miscible with alcohol, ether, benzene, chloroform, solvent naphtha, and most of the fixed solvent oils; and it is noncombustible, nonexplosive, and relatively inert.

Alternative names: tetrachloromethane; carbon chloride; methane tetrachloride; methane, tetrachloro-; perchloromethane (20,36,68,80,108).

Synonyms: Benzinoform; Carbona; Carbon tet; CAS 56-23-5; Dowfume 75; ENT 4075; Flukoids; Halon 104; Necatarina; R10; Tetrafinal; Tetraform; Tetrasol; Univerm; Vertifume; Vermoestricid (20,36,68,80,108).

Some other important properties are as follows (76):

Molecular weight = 153.84

Molecular formula = CCl_4

Boiling point = 76.8°C

Freezing point = -22.8°C

Vapor density = 5.32 (air=1)

Specific gravity = 1.585 g/ml at 25°C

Vapor pressure = 114.5 mm Hg at 25°C

Concentration of gas in air at 25°C and 760 mm Hg pressure (example):

$$1 \text{ lb}/1,000 \text{ ft}^3 = 16 \text{ g}/\text{m}^3 = 0.254\% = 2,543 \text{ ppm}$$

$$\text{*TLV} = 0.06 \text{ g}/\text{m}^3 = 0.001\% = 10 \text{ ppm}$$

Solubility in water - 0.08 g/100 ml at 20°C

*TLV - Threshold Limit Value, American Conference of Governmental Industrial Hygienists (1980).

VIII. Pest Information

Of the nearly one million identified insect species only a few are considered to be serious pests of stored grain. Cotton and Wilbur (30) list 19 species as major insect pests of stored grain and 22 other species as minor pests frequently encountered in stored grain (Table 1). Most of these insects are cosmopolitan species found throughout the world wherever grain is harvested and stored. It is characteristic of these insects that their development period is short, their rate of reproduction is high, and individual insects are long-lived.

Most of the important insect pests of stored grain are either beetles or moths. Insects in each of these groups have four life stages: Egg, larva, pupa, and adult. The principal damage is caused by the feeding of the larval stages, although adults (whose primary function is reproduction and the spread of the species) of most beetles will also feed on the grain.

Grain insects are generally divided into two groups: Those species that develop inside kernels of grain and comprise the "hidden infestation" in a grain mass and those that develop outside the kernel by feeding on broken kernels, the germ portion of kernels, on grain dust, or on flour or other cereal products (30). The USDA Agriculture Handbook No. 500 (7) identifies five internally developing species that cause most of the damage to grain in storage and shipment. These are the rice weevil, Sitophilus oryzae (Linnaeus); maize weevil, S. zeamais Motschulsky; granary weevil, S. granarius (Linnaeus); lesser grain borer, Rhyzopertha dominica (Fabricius); and the Angoumois grain moth, Sitotroga cerealella (Olivier). The larval stage of each develops within a kernel of grain where it feeds unseen and usually unsuspected. These species cannot be removed from grain by cleaning procedures, but must be controlled by other means, such as with chemical pesticides. They are the source of most of the insect fragments found in milled cereal products.

Table 1. Alphabetical list of the major and minor insect pests of stored grain (30).

Scientific Name	Common Name	Family
MAJOR PEST OF STORED GRAIN		
<u>Acarus siro</u> L.	grain mite	Acaridae
<u>Anagasta kuehniella</u> (Zeller)	Mediterranean flour moth	Pyralidae
<u>Cryptolestes ferrugineus</u> (Stephens)	rusty grain beetle	Cucujidae
<u>Cryptolestes pusillus</u> (Schönherr)	flat grain beetle	Cucujidae
<u>Cryptolestes turcicus</u> (Grouv.)	flour-mill beetle	Cucujidae
<u>Ephestia cautella</u> (Walker)	almond moth	Pyralidae
<u>Ephestia elutella</u> (Hubner)	tobacco moth	Pyralidae
<u>Oryzaephilus surinamensis</u> (L.)	sawtoothed grain beetle	Cucujidae
<u>Oryzaephilus mercator</u> (Fauvel)	merchant grain beetle	Cucujidae
<u>Plodia interpunctella</u> (Hübner)	Indianmeal moth	Pyralidae
<u>Rhyzopertha dominica</u> (F.)	lesser grain borer	Bostrichidae
<u>Sitophilus granarius</u> (L.)	granary weevil	Curculionidae
<u>Sitophilus oryzae</u> (L.)	rice weevil	Curculionidae
<u>Sitophilus zeamais</u> Motschulsky	maize weevil	Curculionidae
<u>Sitotroga cerealella</u> (Olivier)	Angoumois grain moth	Gelechiidae
<u>Tenebroides mauritanicus</u> (L.)	cadelle	Trogositidae
<u>Tribolium castaneum</u> (Herbst)	red flour beetle	Tenebrionidae
<u>Tribolium confusum</u> Jacquelin duVal	confused flour beetle	Tenebrionidae
<u>Trogoderma granarium</u> Everts	Khapra beetle	Dermestidae
MINOR PEST OF STORED GRAIN		
<u>Ahasverus advena</u> (Waltl)	foreign grain beetle	Cucujidae
<u>Alphitobius diaperinus</u> (Panzer)	lesser mealworm	Tenebrionidae
<u>Areceus fasciculatus</u> (De Geer)	coffeebean weevil	Anthribidae
<u>Attagenus megatoma</u> (F.)	black carpet beetle	Dermestidae
<u>Carpophilus dimidiatus</u> (F.)	corn sap beetle	Nitidulidae
<u>Carpophilus hemipterus</u> (L.)	driedfruit beetle	Nitidulidae
<u>Caulophilus oryzae</u> (Gyllenhal)	broadnosed grain beetle	Curculionidae
<u>Corcyra cephalonica</u> (Staint.)	rice moth	Galleriidae
<u>Cynaues angustus</u> (LeConte)	larger black flour beetle	Tenebrionidae

Table 1.-- Continued

Scientific Name	Common Name	Family
MINOR PEST OF STORED GRAIN		
<u>Gnathocerus cornutus</u> (F.)	broadhorned flour beetle	Tenebrionidae
<u>Lasioderma serricorne</u> (F.)	cigarette beetle	Anobiidae
<u>Latheticus oryzae</u> Waterhouse	longheaded flour beetle	Tenebrionidae
<u>Liposcelis</u> spp.	psocids	Psocoptera
<u>Palorus ratzeburgi</u> (Wissmann)	small-eyed flour beetle	Tenebrionidae
<u>Palorus subdepressus</u> (Wollaston)	depressed flour beetle	Tenebrionidae
<u>Prostephanus truncatus</u> (Horn)	larger grain borer	Bostrichidae
<u>Ptinus claviceps</u> Panzer	brown spider beetle	Ptinidae
<u>Ptinus villiger</u> (Reitter)	hairy spider beetle	Ptinidae
<u>Stegobium paniceum</u> (L.)	drugstore beetle	Anobiidae
<u>Tenebrio molitor</u> L.	yellow mealworm	Tenebrionidae
<u>Tenebrio obscurus</u> F.	dark mealworm	Tenebrionidae
<u>Tribolium audax</u> Halstead	black flour beetle	Tenebrionidae
<u>Trogoderma</u> spp.	grain-feeding dermestids	Dermestidae
<u>Typhaea stercorea</u> (L.)	hairy fungus beetle	Mycetophagidae

Other insect species, such as the flat grain beetle, Cryptolestes pusillus (Schonherr); the rusty grain beetle, C. ferrugineus (Stephens); the confused flour beetle, Tribolium confusum Jacquelin duVal; the red flour beetle, T. castaneum (Herbst); the sawtoothed grain beetle, Oryzaephilus surinamensis (Linnaeus); Indianmeal moth, Plodia interpunctella (Hubner); and almond moth, Ephestia cautella (Walker), are externally developing species that can cause much damage to grain if storage conditions favor their proliferation. Although some can attack whole kernels, population development of these secondary pests is enhanced by grain dust or broken kernels produced by mechanical injury during handling or by feeding activity of the primary insect pests. Some secondary species will eat into the germ area of a kernel where they are not easily detected or dislodged during cleaning; thus, in effect they become "internal feeders."

Information relative to insect populations in grain during its storage and transport has been developed at opposite ends of the U.S. marketing system: export and farm storage. Insects were characterized by incidence, density, and species composition in 4,441 samples of wheat and corn exported from 79 elevators during a 2-year period, 1977-78 (104) (Table 2). One or more live insects were found in 22.4 percent of the corn samples and 17.9 percent of the wheat samples. Sitophilus spp. (rice and maize weevils) were the predominant insects found in both grains; 7.7 percent of the wheat samples contained an average of 4.2 weevils per 1000 grams and 14.4 percent of the corn samples contained an average of 5.8 weevils per 1000 grams. Cryptolestes spp. (flat and rusty grain beetles) were the second most frequently found insect pests in the export samples; 7.5 percent of the wheat samples contained an average of 1.9 insects per 1000 grams, and 9.7 percent of the corn samples contained an average of 2.4 insects per 1000 grams. Lesser grain borers ranked third among species found in wheat, and Indianmeal moth ranked third among species found in corn.

Table 2. Insect species and population densities found in 1977-78 corn and wheat exports (104).

Insect species	Corn samples		Wheat Samples	
	Percent infested	Density/ 1,000 g	Percent infested	Density/ 1,000 g
<u>Sitophilus</u> spp. (maize and rice weevils)	14.4	5.8	7.7	4.2
<u>Cryptolestes</u> spp. (flat and rusty grain beetles)	9.7	2.4	7.5	1.9
<u>Rhyzopertha dominica</u> (F.) (lesser grain borer)	0.3	0.7	5.6	4.3
<u>Plodia interpunctella</u> (Hubner) (Indianmeal moth)	1.6	39.9	1.2	21.5
<u>Anagasta kuehniella</u> (Zeller) (Mediterranean flour moth)	0.2	4.3	0	--
<u>Tribolium</u> spp. (red and confused flour beetles)	0.3	1.1	0.4	1.1
<u>Ephestia cautella</u> (Walker) (almond moth)	0.2	55.5	0.1	2.1
<u>Sitotroga cerealella</u> (Olivier) (angoumois grain moth)	0.2	1.0	0	--
<u>Tenebroides mauritanicus</u> (L.) (cadelle)	0.2	1.0	0	--
<u>Oryzaephilus surinamensis</u> (L.) (sawtoothed grain beetle)	0.1	0.2	0.3	4.0
Dermestids (Trogoderma spp.)	0	--	0.1	0.1
Misc. beetles (<u>Typhaea stercorea</u> (L.), hairy fungus beetle) (<u>Ahasverus advena</u> (Waltl.))	0.1	13.7	0	--
<u>Liposcelis</u> spp. (psocids)	0.5	-- <u>b</u> /	0.1	-- <u>b</u> /
<u>Acarus siro</u> L. <u>a</u> / (grain mites)	30.0	-- <u>b</u> /	0	-- <u>b</u> /
Average percent infested <u>c</u> /	22.4		17.9	

a/ 1977 samples only.

b/ Density not calculated.

c/ Psocids and mites omitted.

Other insect species were detected in generally less than 0.5 percent of the export samples. In 1980, insects in farm storage were determined in 4,171 bins of wheat, 2,918 bins of corn and 1,050 bins of oats across 27 States (106). Live insects were found in 25.1% of the wheat samples, 56.4 percent of the oat samples, and 79.7% of the corn samples. The average insect density per 1000 grams in the infested samples for all species combined was higher in wheat (105 per 1000 grams) than in oats (39 per 1000 grams) or corn (26 per 1000 grams). The insect densities were applicable only to those samples in which live insects were detected and do not represent an overall insect average in all samples examined. Cryptolestes spp. (flat and rusty grain beetles) were the predominant insects in wheat and corn and sawtoothed grain beetle the predominant species in oats (Table 3). Corn contained the widest variety of insects (23 species or groups of species) and it was not uncommon for individual samples to contain as many as five or six different species. Insect species that prefer high moisture conditions or feed on molds or decaying vegetable matter were found in 28.8 percent of the corn samples compared to 12.7% of the oats and 6.3% of the wheat.

Farm-stored corn and wheat in Minnesota were sampled for insects during 1977 and 1978 (15). The most common insects, in decreasing order, were Cryptolestes spp; foreign grain beetle, Ahasverus advena (Waltl); Indianmeal moth; larger black flour beetle, Cynaues angustus (Leconte); red flour beetle; hairy fungus beetle, Typhaea stercorea (Linnaeus); and sawtoothed grain beetle. Of 38 bins of shelled corn, 10 had 15 or more live adult insects per 0.95-liter (1 qt) sample and 15 bins had 5 to 14 insects per 0.95-liter sample. Surveys of farm stored grain in Kansas (18) showed high concentrations of lesser grain borer, sawtoothed grain beetle, red flour beetle, flat grain beetle, Indianmeal moth, hairy fungus beetle, and foreign grain beetle.

Table 3. Species, percentage incidence, and average density of insects in wheat, corn, and oats stored on the farm (106).

Insect species	Wheat samples		Corn samples		Oat samples	
	Percent infested	Density/1,000 g	Percent infested	Density/1,000 g	Percent infested	Density/1,000 g
<u>Cryptolestes spp.</u> (flat and rusty grain beetles)	13.8	(45)	57.7	(18)	16.7	(34)
<u>Oryzaephilus surinamensis (L.)</u> (sawtoothed grain beetle)	7.9	(30)	9.3	(17)	39.9	(206)
<u>Plodia interpunctella (Hubner)</u> (Indianmeal moth)	0.8	(450)	27.6	(107)	0	
<u>Tribolium spp.</u> (red and confused flour beetles)	1.7	(76)	19.4	(12)	4.3	(112)
<u>Liposcelis spp.</u> (psocids)	4.2	(-)	1.4	(-)	11.3	(-)
<u>Ahasverus advens (Waltl)</u> (foreign grain beetle)	0.02	(4)	16.0	(21)	0	
<u>Sitophilus spp.</u> (rice, maize and granary weevils)	0.8	(146)	9.4	(50)	2.6	(59)
<u>Dermestids</u> (<u>Trogoderma</u> , <u>Attagenus</u> , <u>Dermestes spp.</u>)	1.7	(24)	3.7	(13)	3.7	(31)
<u>Rhyzopertha dominica (Fabricius)</u> (lesser grain borer)	2.6	(160)	0.4	(7)	0.5	(23)
<u>Cynaues angustus (LeConte)</u> (larger black flour beetle)	0.1	(3)	6.9	(9)	1.2	(6)
<u>Tenebroides mauritanicus (L.)</u> (cadelle)	0.1	(2)	3.3	(9)	0.8	(10)
<u>Typhaea stercorea (L.)</u> (hairy fungus beetle)	0		3.2	(6)	0.1	(4)
<u>Tribolium audax (Halstead)</u> (black flour beetle)	0.04	(3)	0		0.8	(16)
<u>Ptinus spp.</u> (spider beetles)	0.02	(3)	0.3	(7)	0.2	(2)
<u>Murmidius ovalis (Beck)</u> (minute beetle)	0		0.6	(62)	0	
<u>Platydema ruficorne (Sturm)</u> (redhorned grain beetle)	0		0.3	(5)	0	
<u>Tenebrio molitor (L.)</u> (yellow mealworm)	0.04	(6)	0.2	(4)	0	
<u>Nemapogon granella (L.)</u> (European grain moth)	0		0.2	(10)	0	
<u>Sitotroga cerealella (Olivier)</u> (Angoumois grain moth)	0		0.1	(289)	0	
<u>Alphitophagus bifasciatus (Say)</u> (twobanded fungus beetle)	0		0.1	(7)	0	
<u>Cathartus quadricollis (Guerin-Meneville)</u> (squarenecked grain beetle)	0		0.1	(7)	0	
<u>Latheticus oryzae (Waterhouse)</u> (longheaded flour beetle)	0.02	(831)			0	
<u>Carpophilus dimidiatus (Fabricius)</u> (corn sap beetle)	0		0.1	(2)	0	
<u>Lophocateres pusillus (Klug)</u> (Siamese grain beetle)	0.02	(2)	0.1	(1)	0	
<u>Gastocerus maxillosus (Fabricius)</u> (slenderheaded flour beetle)			0.1	(6)		
ALL SPECIES	25.1	(92)	79.7	(34)	56.4	(39)

Many of the insect pests found in stored grain are also major pests of ground or processed cereal products. In a national survey (78) extension personnel in 44 States responded to the question: "Which stored product insects cause the biggest problems in your State on processed food?" (Table 4). Over half of the states listed sawtoothed grain beetle, Indianmeal moth, Dermestid beetles, and red flour beetles as problem pests in processed food. Insects such as these are able to enter the many recesses and cavities in processing machinery where the product tends to remain static during normal operation. Insects multiply rapidly in this material and soon contaminate the finished product as it passes through the machine. Insects damage grain directly by feeding on individual kernels and indirectly by contaminating the grain with their feces, webbing, cast skins, and body parts. They also contribute to the conditions that cause heating and molding of grain. According to regulations enforced by the Food and Drug Administration (FDA), when infested grain is processed, insect fragments in the milled products may be sufficient to cause the product to be diverted from human food to animal feed or even to fertilizer.

Market value of infested grain may be substantially reduced if the number of insect-damaged kernels is sufficient to lower the grade of the grain (total damage factor), or if the number of insects in the grain causes it to be designated "weevily" or cause the grain to have a "commercially objectionable foreign odor." Discounts against the price paid per bushel are often assessed by the buyer if live insects are present in the grain. Discounts for infested grain in Minnesota (16) were reported to range from 2-10¢/bushel for corn and 3-15¢/bushel for wheat. Country elevators in western Kansas and eastern Colorado reported discounts of 12 1/2¢/bushel being applied to infested wheat by terminal elevators during the fall of 1981 (100). Some grain dealers may refuse to accept grain with heavy infestation that might spread throughout their storage facilities.

Table 4. Responses from extension personnel in 44 states to the question:
Which stored product insects cause the biggest problems in your state
on processed food? (78)

Rank	Number States	Insect	Scientific Name
1	33	Saw-toothed grain beetle	<u>Oryzaephilus surinamensis</u> (L.)
2	29	Indianmeal moth	<u>Plodia interpunctella</u> (H.)
3	24	Dermeestids	Various kinds
4	24	Red flour beetle	<u>Tribolium castaneum</u> (H.)
5	15	Confused flour beetle	<u>Tribolium confusum</u> Jacquelin duVal
6	13	Cigarette beetle	<u>Lasioderma serricorne</u> (F.)
7	6	Drug-store beetle	<u>Stegobium paniceum</u> (L.)
8	3	Merchant grain beetle	<u>Oryzaephilus mercator</u> (F.)
9	3	Psocids (Booklice)	<u>Liposcelis</u> spp.
10	3	Mites	Various kinds
<u>Others listed</u>			
11	2	Flat grain beetle	<u>Cryptolestes pusillus</u> (S.)
12	2	Rice weevil	<u>Sitophilus oryzae</u> (L.)
13	2	Almond moth	<u>Ephestia cautella</u> (W.)
14	2	Foreign grain beetle	<u>Ahasverus advena</u> (W.)
15	1	Mediterranean flour moth	<u>Ephestia kuehniella</u> (Z.)
16	1	Angoumois grain moth	<u>Sitotroga cerealella</u> (O.)
17	1	Meal-worms	<u>Alphitobius</u> spp.
18	1	Square-necked grain beetle	<u>Cathartus quadricollis</u> (G.M)
19	1	Dried fruit beetle	<u>Carpophilus hemipterus</u>
20	1	Brown spider beetle	<u>Ptinus clavipes</u> (P.)

Foreign sales of grain produced in the United States are important to the economy of the individual grain producer and to the trade balance of the nation. Competition among grain-producing countries for export markets has substantially increased during recent years. Although price and supply have been the major factors in determining the volume of grains that a nation could sell in world markets, grain quality has become increasingly important to successful marketing (101). The presence of insects in grain during storage and transport greatly affects its quality. Low levels of insect infestation in farm-stored grain can develop into damaging populations before the grain reaches its final destination. It is essential, therefore, that grain in the U.S. marketing system be kept free of these pests to ensure its acceptance by both domestic and foreign grain buyers.

Problems concerning the quality of grain exported from the United States have been significantly magnified by the rapid expansion of export markets. One of the determinants of grain quality is the level of insect infestation associated with grain during its storage and transport in the marketing system. The Federal Grain Inspection Service (FGIS) of the USDA has reported that "...insect infestation is a major issue. It is a source of foreign complaints about the quality of U.S. grains and correction of the [grade] standards to better reflect insect infestation is of high priority" (6). Another report issued by the U.S. General Accounting Office (GAO) stated that "...according to several major foreign buyers, the most significant and prevalent quality problem with U.S. grains involve infestation and lack of adequate fumigation" (8). The GAO report attributes the insect problem in exports from the United States to two principal factors involved in inspection of grain. First, insects detected during sampling and grading of grain are not disclosed on inspection certificates unless they exceed certain tolerance levels established by FGIS.

Second, present inspection methods cannot determine the hidden or "latent" infestations of internally developing insect species nor can they readily detect eggs or some larval stages of externally developing species that feed deep inside the germ portion of a kernel of grain. Subsequently, neither the interⁿval nor any other larval (immature) stage of development is taken into account for grain grading purposes.

A 1978 interior grain market survey conducted by the Economics, Statistics and Cooperatives Service (ESCS) in cooperation with the Federal Grain Inspection Service (FGIS) collected information concerning grain inspection and weighing services (5). Several of the questions posed to grain elevator operators and grain processors dealt with insect infestations. Live insects were considered an important quality for buying wheat in over 60 percent of the elevators surveyed. Dead insects were also considered important, but to a lesser degree. Processors considered both live and dead insects almost equally important. The majority of grain elevators indicated that the current standards for insect tolerances were too tight. The response from wheat millers and dry corn millers was just the opposite with the majority expressing the opinion that the present standards are too liberal.

No "economic thresholds" have been established for stored-grain insects. Each grain mass has a unique combination of insect species and numbers, moisture contents, temperature, fungi, damaged grain, and type of grain. The various species of insects cause different types and amounts of damage. All of these variables make it impossible, at present, to sample a mass of grain and, from numbers and species of insects present, to accurately predict the amount of damage that will occur in a given period. A 1972 study of insect damage by the Food and Drug Administration (FDA) and the Grain Division, Agricultural Marketing Service, reported that among 1,200 samples of various grades of wheat, 35 percent contained insect-damaged kernels (37).

Cotton (28) estimated that infested and undisturbed wheat in the Great Plains Region could suffer a loss as high as 10 percent in one season and corn in the deep South could be destroyed at the rate of 9 percent per month while it is in storage. A 1962 study of insect damage to corn in the Southern States at time of harvest and in storage reported an estimated loss of nearly 10 million dollars in the three-State area of Georgia, Alabama, and Mississippi (35). No recent estimates of losses from insect damage to grain stored in the United States are available. USDA reported (13) estimated annual storage losses caused by insects during the 10-year period ending 1960 at 324.5 million bushels of corn, wheat, barley, sorghum, and oats. At that time, the annual loss was about \$454 million.

Actual loss is rarely determined by weighing grain before and after infestation. If this is done; however, the increased uptake of moisture by infested grains and the presence of insect biomass and insect excrement may compensate for, or obscure, the weight losses due to infestation. Studies that deal with quality loss rather than quantity loss have shown that a breakdown of fatty acids and an accelerated increase in oxidative rancidity occurs in some grains as a result of insect activity (51). Sedimentation values, gluten, and ash are also decreased as a result of insect infestation (40). Studies of consumption and utilization by individual insects have shown that complete development of a granary weevil within a wheat kernel requires consumption of 62.2 percent of the estimated 0.126 Calories available in a single kernel of wheat. Of the amount consumed by the weevil, 22.8 percent is excreted in feces or other excretory products and the remaining 77.2 percent is assimilated by the weevil (52).

Ungsunantwiwat (109) observed the following mean percentage weight losses of individual kernels of grain as a result of development of one weevil in each:

	Mean percent weight loss		
	<u>Wheat</u>	<u>Sorghum</u>	<u>Corn</u>
Maize weevil	40	48	9.5
Rice weevil	29.5	37.5	
Granary weevil	43.5	51.5	

The above values were calculated on a wet-weight basis, and feces and exuviae were not removed from the kernels. Therefore, the values are conservative as neither contamination nor relative losses of various nutrients were taken into account.

LeCato (64) placed five pairs of insects/100-gram sample of wheat, and after 12 weeks weight losses of the wheat ranged from 0 to 0.1 gram for flat grain beetles, sawtoothed grain beetles, or red flour beetles; 5.3 to 6.2 for lesser grain borers and rice weevils; and 1.1 to 9.5 for different two-species combination.

Sixteen weeks after 25 sawtoothed grain beetles were placed in each 50-gram sample of 'Capelle' wheat, weight losses of the wheat ranged from 0.78 to 1.37 grams, and the final insect population ranged from 140 to 216 insects per sample (107).

Campbell and Sinha (26) observed a mean 3.69 percent weight loss of single wheat kernels caused by individual rusty grain beetle larvae, 17.15 percent for lesser grain borers, and 63.6 percent for granary weevils. They found that during a 48 hour period of feeding, individual adults of the rusty grain beetle, lesser grain borer, and granary weevil reduced the dry weight of single kernels 0.78, 6.17, and 5.59 percent, respectively.

These selected examples of damage measured in laboratory tests provide quantitative evidence that damage does occur in stored grain, that different species vary in the amount and type of damage they cause, and that some species are potentially much more serious pests than others.

In a study (106) of test weight differences between infested (one or more live insects per sample) and uninfested farm stored grain, infested wheat was found to average 0.8 lb per bushel lighter than uninfested wheat, infested corn was 0.7 lb lighter and infested oats 0.5 lb lighter (37). An estimate of the significance of this weight loss may be obtained by projecting the average weight difference between infested and uninfested grain together with the percentages of farm grain found to contain live insects, to the estimated stocks of wheat, corn, and oats stored on the farm.

<u>Factor</u>	<u>Wheat</u>	<u>Corn</u>	<u>Oats</u>
Bushels stored on-farm (3-year average)	1,200,000,000	4,600,000,000	400,000,000
Pct with live insects (farm survey)	25.1	79.7	56.4
Bushels infested	301,200,000	3,666,200,000	225,600,000
Weight loss per bushel (lb)	0.8	0.7	0.5
Pounds of grain lost	240,060,000	2,566,340,000	112,800,000
Average test weight uninfested grain	60.0	58.1	37.4
Bushels lost	4,016,000	44,171,084	3,016,043

Less direct insect damage results when infested grain is processed into human or animal food. Insect fragments present in the milled products could cause the products to be declared unfit for human consumption and rejected by the FDA. The relationship of insects in grain to their fragments in flour is influenced by a number of factors including the species involved, whether the

insects are live or dead, the type of grain being processed, the size and flow of the milling operation, and the type of equipment used prior to and after milling. Two early studies (48,49) give some indication of the relationship between insects present and the resulting fragments. On the average, one insect in cleaned corn resulted in 12.5 insect fragments in finished bolted cornmeal. Studies with wheat showed that one internal insect resulted in 13.2 fragments, two internal insects in 24.5 fragments, and three internal insects in 44.3 fragments in the flour.

Other damage caused by insects in food processing plants is less direct and may involve more than just loss of the infested material. For example, a dealer, distributor, or warehouse receiving an insect complaint from a consumer would normally relay the information to the basic manufacturer or supplier. Time and effort expended by a company representative to investigate the problem and determine the validity of the complaint are expensive, but are considered as part of the cost of doing business. Cost of the product involved can be precisely documented, but it is a small part of the total expense involved.

Insects may also enter finished products during production and create a pest problem elsewhere in the marketing channel. For example, living dermestids might enter a package of cake mix, multiply, escape in a far distant warehouse, and contaminate other products in storage; or they might end up in a home kitchen and here also contaminate other food. Such infested products may be diverted to animal feed, which is usually of lower value, or simply discarded, thus wasting valuable food.

Some individuals become highly emotional when finding insects in a package of food. Many housekeepers will undoubtedly purchase an insecticide to spray the home kitchen- "to get rid" of those "bugs" that came in with the flour, cake mix, or cereal, thus needlessly exposing the housekeeper and family to insecticides.

Data presented in this section demonstrate three factors relative to insect infestations in cereal grains and their products. First, grain in the U.S. marketing system contains a significant level of insect infestations in farm stored grain that is still present at the time it is processed or exported; second, controlled studies document a variety of specific quality and quantity losses that may occur to grain as a result of insect attack; and third, actual direct and indirect losses caused by insects during the storage and marketing of grain and grain products are difficult to quantify; therefore, data generally are not available.

Recent actions taken by grain marketers and by various government agencies are symptomatic of increased insect problems in U.S. grain. Some selected examples are:

1. Reports of insect discounts applied to producers delivering grain to country elevators and to grain shipped from country elevator to terminal markets have increased significantly during recent years (16,100).
2. The FGIS announced its intention to review procedures to improve the special grade "weevily" because of concerns about insects in export grain (Federal Register 44FR76835, Dec. 28, 1979).
3. FGIS established^e procedures to permit the fumigation of infested grain in bulk dry-cargo ships after the loading of grain was complete. When fumigated by specified procedures, reinspection of the grain is not required (4).
4. FGIS established an Interim-Policy that relieved inspectors of the responsibility of reinspecting grain in boxcars that had previously been graded weevily and were subsequently fumigated to eliminate the infestation (Interim Policy - Certification of Grain in Boxcars After Fumigation, June 5, 1980; FGIS.)

5. The Animal and Plant Health Inspection Service (APHIS) and FGIS developed an agreement to jointly aid applicants in obtaining phytosanitary inspection services at export locations in response to requests from purchasing nations for phytosanitary certification of U.S. grain shipments (14).
6. The FDA established a new compliance Policy Guide (7104.02) for wheat flour adulterated with insect fragments that sets a defect action level of an average of 50 insect fragments or more per 50 grams of flour.
7. The Agricultural Stabilization and Conservation Service (ASCS) reported that steps are being taken to educate producers of the need to improve caretaking of grain in the farmer-owned reserve (13).
8. The Agricultural Research Service (ARS) released an updated Farmer's Bulletin on controlling insects in farm stored grain (101) and also greatly expanded research on intransit fumigation of grain in cooperation with FGIS.
9. The National Grain and Feed Association's Fire and Explosion Research Committee updated its industry standards for fumigation in grain elevators (9).

Each of these actions is indicative of the expanded role insects play in the marketing of U.S. grain and milled products.

Closer inspections, possible lower insect tolerances, expanded education efforts and policies that allow the application of remedial treatments just prior to or during delivery of the grain suggests that fumigation is an essential marketing practice without which grain would not meet existing standards. In actual practice, a relatively small amount of the grain produced and marketed is ever fumigated. The reason for this contradiction is

principally economic. Expressed in the simplest of terms, very little 6-8-dollar-a-gallon fumigant is going to be applied to wheat selling at \$4.00/bushel or to corn selling at \$3.00/bushel unless the level of insect activity prevents the further marketing of the grain. In a study of purchasing policies regarding infested grain brought out of farm storage in Minnesota (13), it was concluded that, "Based on current retail values, the cost of fumigating grains vs. the potential loss from discounting may not justify fumigation". The study also indicated that farmers were not given credit for preventing insect infestation. In a limited survey of 23 bins in one county of Nebraska (93) it was observed that "two-thirds of the bins examined had a high enough insect population to warrant control." Many of the producers surveyed, however, reported that when they encountered problems with grain in the Farmer-owned Grain Reserve Program, instead of treating the grain, they rotated it with new grain after receiving permission from the county ASCS office.

Grain shipped to port elevators for export may contain "hidden infestations" of insects which are usually those species that develop inside kernels of grain. The infested grain may proceed undetected through the marketing channel only to have the insects emerge in large numbers when the grain is received at the overseas markets.

In a study of insect infestation conducted for a 17-month period in 1977-79 at one export grain elevator in Houston, Texas, 597 samples were examined for insect infestation (22). Only 6 (1 percent) were found to be infested at the time of shipment based on the requirement standards and visual observations. Four hundred and fifty-nine of these samples were reexamined by IR-CO₂ analysis for hidden insect infestations (21), interpretation of x-ray photographs of the samples, and by incubation of the samples to develop any

hidden infestation. Live infestations or dead insects were found in 440 of these samples. The number of insects per sample was not presented in this study; however, of the samples examined, 45 percent contained weevils, 4 percent contained lesser grain borers, and 21 percent contained various moth larvae.

In contrast to the common species of insects that infest both domestic and export grains, the important species on/in imported products are quite different. The United States plant quarantine regulations require that seeds and nursery stock entering the country be free of insects and plant diseases which do not occur or are not widely distributed in the U.S. (110). For example, many species of flies (midges) in the family Cecidomyiidae and wasps (chalcids) in the family Torymidae are phytophagous and infest the seeds of plants. Presently, there are 33 described species of the genus Megastigmus Dalman alone that develop in the seeds of conifers. Of these, 21 species do not occur in North America (67). Some occur in one species of conifer, others in several species or genera. Females oviposit one or more eggs on an ovule or embryo during early stages of cone formation, but only one larva develops to maturity in a seed which is subsequently completely destroyed except for the seed coat. Normally, there is only one generation per year and pupation occurs the following spring. A small percentage of larvae require two or more years before pupating.

Damage to seed from the insect can be severe. One species, Megastigmus strobilobius (Ratzeburg), often found during quarantine inspections, was reported as frequently damaging 75-100 percent of the viable seeds of fir resulting in incomplete reforestation of cutover areas (34). In general, when an insect pest becomes established in a new environment, it causes more damage than it does in its native habitat. When M. spermotrophus Wachtl was introduced

into Scotland in seeds of Douglas fir, it increased within nine years until the cones were no longer worth collecting for seed. Even when infestation is not high, the cost of cone collection for seed may be increased greatly (70).

IX. Biological and Economic Information

A. Stored Grain and Milled Products

1. On-Farm Storage

On-farm storage of grain in the United States is principally in circular metal bins. The average storage bin has a capacity of ca. 6,000 bushels. There are many types of storage bins, with the main difference being in the ventilation systems. The older style grain bins have a solid floor with no forced-air ventilation or a modified floor, fan and ducting. The newer style storage bins have ventilated false floors and an 18-inch plenum chamber to allow for maximum air movement.

In 1972, the U.S. Department of Agriculture (USDA), Agricultural Stabilization and Conservation Service (ASCS), offered low interest loans to farmers for the purchase of grain storage structures. The program offered loans for five categories of storage equipment: 1) Storage structures (unvented bins, quonset huts, flat storage), 2) grain dryers, 3) drying bins (vented/with forced air drying), 4) wet storage (trenches, pits, flat storage, and so forth, and 5) forage silos. Only categories 1 and 3 are subject to treatment with typical grain fumigants.

The number and amount of loans issued to date by ASCS for categories 1 and 3 are as follows:

	<u>No. of Loans</u>		<u>Amount of Funds</u>	
	<u>State of Minn.</u>	<u>Natl.</u>	<u>State of Minn.</u>	<u>Natl.</u>
Category 1	21,000	97,000	\$93.2 mil	\$524.1 mil
Category 3	4,400	65,000	\$40.4 mil	\$521.0 mil

The actual number of structures built was not determined by ASCS. However, knowing the average loan price per bushel (\$0.75-0.80) and the average size per structure, one could estimate an average of \$4,000 each. This loan program was discontinued on February 1, 1982.

With few exceptions, most of the modern grain storage structures used on the farm today can be treated with any of the currently registered grain fumigants, 80-20 mixtures (CCL₄ and CS₂ or CCl₄ and EDC, and so forth), aluminum phosphide, chloropicrin, and so forth. The exceptions are criblike structures.

The storage capacity for United States on-farm stored grain has been steadily increasing in the past decade, from 4.6 billion bushels in 1970 to 9.6 billion bushels in 1981 (81). The increase is due primarily to farmers wanting to avoid the increasing storage and drying costs at commercial grain handling facilities and to have more market flexibility.

The total of stored-grain capacities in the United States in 1981 was 16.8 billion bushels (116), of which on-farm stored grain capacities represent 57 percent of the U.S. totals.

Statistics for Individual States
On-Farm Stored-Grain Stocks, 1981

Jan. 1, 1981 <u>(x1,000 bu)</u>		<u>(x1,000 bu)</u>		<u>(x1,000 bu)</u>	
Alabama	6,987	Maryland	9,278	Oregon	26,100
Arizona	2,572	Michigan	86,377	Pennsylvania	51,879
Arkansas	11,098	Minnesota	564,380	South Carolina	10,074
California	33,574	Mississippi	7,107	South Dakota	245,127
Colorado	85,326	Missouri	93,764	Tennessee	15,635
Delaware	1,276	Montana	222,941	Texas	28,083
Florida	2,717	Nebraska	275,286	Utah	11,119
Georgia	18,069	Nevada	2,404	Virginia	14,201
Idaho	79,540	New Jersey	2,554	Washington	54,378
Illinois	315,364	New Mexico	3,481	West Virginia	2,803
Indiana	123,643	New York	36,553	Wisconsin	178,418
Iowa	638,480	North Carolina	19,578	Wyoming	8,809
Kansas	108,675	North Dakota	497,604		
Kentucky	31,976	Ohio	131,228	TOTAL	4,101,886
Louisiana	6,873	Oklahoma	36,555		(x 1,000)

The current standing of storage capacities per grain (117) (1/183, Grain Stocks, USDA Crop Rep. Serv.) is as follows:

	<u>On Farm</u> <u>(x mil. bu)</u>	<u>Total US Storage</u> <u>(x mil. bu)</u>	<u>Percent on Farm</u>
Corn	5,185.7	6,835.7	75
Soybeans	982.1	1,767.9	55
Wheat	953.3	2,170.6	44
Oats	278.1	323.3	86
Sorghum	248.9	667.7	37
Barley	234.9	338.8	69
Rye	5.6	7.8	71
Flax	3.6	5.8	62
TOTAL	<u>7,892.5</u>	<u>12,117.7</u>	<u>65 Avg.</u>

2. Off-Farm Storage

Off-farm storages are principally commercial elevators or warehouses licensed by State or Federal authorities for the storage and marketing of grain. The U.S. grain-handling system is comprised of over 15,000 off-farm grain handling and storage facilities with an estimated capacity in January 1981 of nearly 7.2 billion bushels.

Statistics for Individual States -- Off-farm commercial grain storage capacity by States:

	January 1, 1981 (x 1,000 bushels)
Alabama	39,240
Arizona	29,990
Arkansas	213,490
California	98,540
Colorado	97,580
Delaware	18,400
Florida	7,560
Georgia	66,860
Idaho	77,240
Illinois	827,700
Indiana	292,950
Iowa	735,000
Kansas	848,000
Kentucky	53,340
Louisiana	94,930
Maryland	44,480
Michigan	100,000
Minnesota	400,150
Mississippi	82,500
Missouri	228,350
Montana	54,590
Nebraska	540,520
Nevada	300
New Jersey	2,430
New Mexico	17,220
New York	64,330
North Carolina	73,940
North Dakota	156,860
Ohio	278,170
Oklahoma	212,510
Oregon	66,630

Statistics for Individual States -- Continued

	January 1, 1981 (x 1,000 bushels)
Pennsylvania	31,970
South Carolina	33,630
South Dakota	93,020
Tennessee	55,270
Texas	756,000
Utah	18,150
Virginia	32,090
Washington	191,600
West Virginia	790
Wisconsin	133,970
Wyoming	7,140
Other States	6,100
U.S.	<u>7,183,530</u>

Nearly 45 percent of off-farm storage capacity is located in the States of Kansas, Illinois, Texas, and Iowa.

The actual amount of grain in off-farm storages during each of the years 1978-81 has remained fairly stable and generally represents about half of the estimated storage capacity.

Average Stocks of Stored Grain on January 1, 1978-1981 in Off-Farm Positions (116):

	(Million bushels)
Wheat	<u>1,017</u>
Corn	1,729
Sorghum	384
Barley	115
Oats	75
Rye	4.5
Total	<u>3,324.5</u>

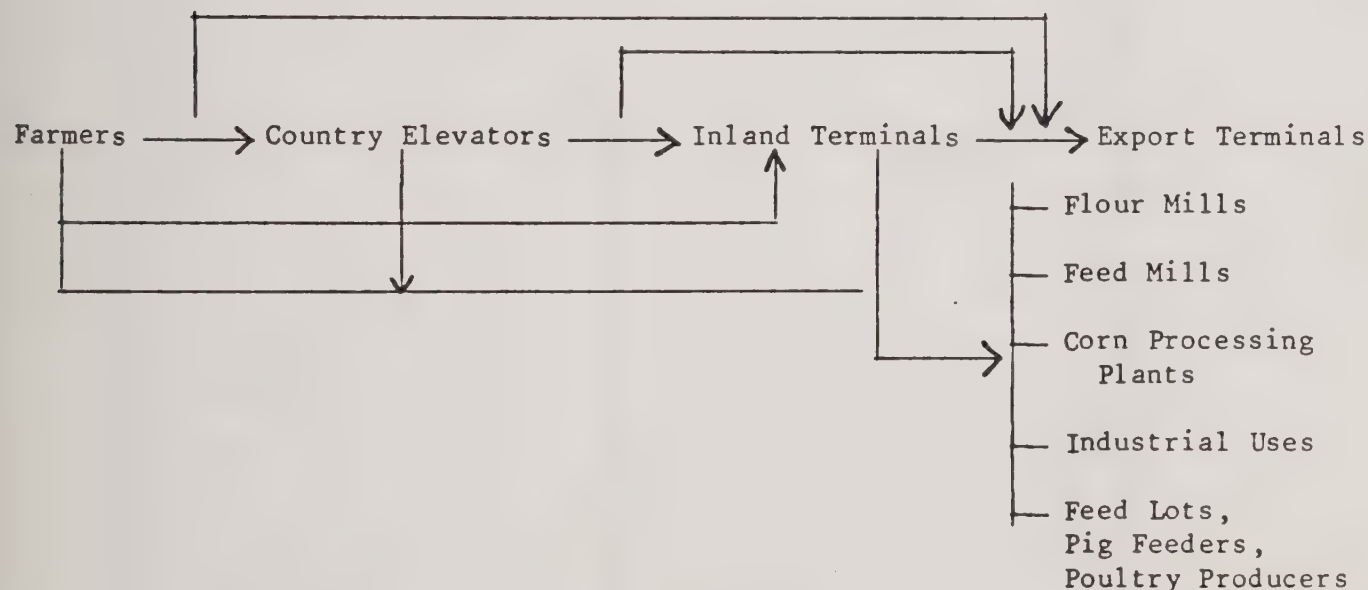
Corn and wheat represent nearly 84 percent of off-farm stored grain stocks (corn 52 pct and wheat 30.6 pct).

There are four general classifications of grain elevators: Country elevators, regional or subterminal elevators, terminal elevators located at railroad and marine centers, and elevators located at processing plants. Country elevators receive grain directly from producers, reload it into trucks and railcars and transport it to other points in the marketing system. Large country elevators approach the size of some terminal elevators and have handling systems capable of receiving and transferring grain at rates of 10,000 to 30,000 bu/h. Regional or subterminal elevators combine functions of both country and terminal elevators and are located at interior points away from major transcontinental pathways. Regional elevators may sell directly to terminal elevators, processors, and exporters and because of their mid-point location, grain may be moved quickly to final market positions when needed. Terminal elevators are, in effect, the end-of-the-line and represent the last stop of grain in the marketing channel before being processed or exported. They are generally located at major crossroad locations with direct access to one or more transportation modes: rail, highway, or water. Although a grain elevator cannot be precisely characterized on the basis of storage capacity alone, most terminals range from 200,000 to 20 million bushels and usually include load-out capabilities of 25,000 to 100,000 bushels/h. Many interior terminals are specifically designed to serve the export market. Sharp (89) identified 251 river barge loading terminals located on 10 waterways and 241 other terminals that load unit train shipments directly to port terminals. U.S. grain exports in 1978 were handled through 81 land-based facilities in the United States and Canada and also through several water-based facilities called floating rigs, which were located on the Mississippi River (114). Many interior terminals and export elevators operate 24 hours each day. The total amount of grain handled

by these facilities represents many consecutive storage loading and emptying operations each year. The major function of these elevators is handling rather than storage.

In a survey conducted by six state grain and feed associations (Illinois, Iowa, Kansas, Minnesota, Nebraska, and Ohio) over 70 percent of the survey respondents indicated that their storage facilities were located in areas with a population of 1,500 or less and nearly half described their location as rural. Only 2.6 percent were located in areas inhabited by 25,500 or more people (88).

U.S. GRAIN MARKETING FLOWCHART



3. Milling and Processing Plants

The flour milling industry, composed of wheat, durum, rye, and dry corn millers, is widely dispersed throughout the United States. Wheat millers dominate the industry both in terms of number of mills and in production capacity of flour.

Wheat Flour Milling by States (Includes soft wheat, and whole wheat flour but excludes durum and rye) (74).

State	Number of Mills	Active Capacity in Hundredweights
Alabama	1	8,800
Arizona	1	1,000
California	10	47,225
Colorado	3	17,000
Delaware	2	472
Florida	2	15,200
Georgia	5	10,570
Hawaii	1	2,200
Illinois	8	66,160
Indiana	7	30,840
Iowa	2	11,100
Kansas (1)	18	119,850
Kentucky	8	4,135
Louisiana	2	11,000
Maryland	1	2,400
Michigan	9	26,550
Minnesota (2)	12	91,800
Missouri	8	70,498
Montana	3	13,500
Nebraska	6	28,970
New Jersey	1	6,200
New Mexico	2	650
New York (3)	14	94,450
North Carolina	14	27,280
North Dakota	1	7,000
Ohio	13	67,925
Oklahoma	4	32,000
Oregon	3	18,700
Pennsylvania	31	36,150
Puerto Rico	2	9,000
South Carolina	4	3,120
South Dakota	1	3,000
Tennessee	17	38,930
Texas	6	38,040
Utah	10	31,420
Virginia	18	21,506
Washington	4	27,550
TOTAL	254	1,042,191

(1) Does not include 5,000 cwts under construction.

(2) Does not include 3,500 cwts under construction.

(3) Does not include 7,000 cwts under construction.

Durum Milling by States

State	Number of Mills	Active Capacity in Hundredweights
Louisiana	1	1,000
Minnesota	5	29,300
New York	3	18,800
North Dakota*	1	5,000
Oregon**	2	8,750
Wisconsin	1	12,000
TOTAL	13	74,850

* Does not include 8,000 cwts under construction.

** 5,000-cwt unit alternates with wheat flour.

Rye Flour Milling by States

State	Number of Mills	Active Capacity in Hundredweights
Illinois	1	144
Minnesota	3	6,600
Missouri	1	350
New York	3	2,480
Ohio	1	400
Texas	1	30
Virginia	1	5
Washington	1	150
TOTAL	12	10,159

Buckwheat Milling by States

State	Number of Mills	Active Capacity in Hundredweights
Indiana	1	80
Minnesota	1	200
Missouri	1	(inactive) 350
New York	3	1,300
Ohio	1	100
Pennsylvania	2	110
Virginia	1	96
TOTAL	10	2,236

Although wheat flour mills are dispersed in 36 States and Puerto Rico, nearly half of the total milling capacity is concentrated in six States: Kansas, Minnesota, New York, Missouri, Ohio, and Illinois. Wheat milling capacity is also concentrated among comparatively few companies. The seventeen largest companies represent only 39 percent of the total wheat flour mills in the United States but have nearly 84 percent of the total wheat milling capacity.

Largest Wheat Flour Milling Companies (74)
(With active daily capacity of 10,000 cwts or more)

Company	Mills	*SWF (cwts)	**WWF (cwts)	Total capacity (cwts)
The Pillsbury Co.	8	31,300	2,500	114,900
ADM Milling Co.	12	5,000	500	95,000
ConAgra, Inc.	16	20,100	--	95,000
Seaboard Allied Milling Corp.	9	5,400	1,000	84,600(1)
Peavey Company	8	16,900	5,400	79,700(2)
International Multifoods Corp.	6	5,400	11,100	59,900
General Mills, Inc.	8	7,200	--	55,100
Cargill Flour Milling Division	4	--	1,000	54,000
Dixie-Portland Flour Mills	5	16,700	192	47,000
Nabisco, Inc.	4	40,000	--	40,000(3)
Bay State Milling Co.	5	3,000	3,550	35,000
Centennial Mills	3	12,000	2,900	27,750
Cereal Food Processors, Inc.	3	5,000	800	23,300
The Mennel Milling Co.	3	21,000	--	21,000
Bartlett Agri Enterprises	3	3,400	--	15,000
Fisher Mills Inc.	1	6,000	1,000	15,000
Tennant & Hoyt Co.	1	--	1,200	11,000
TOTAL	99	198,400	31,142	873,250

*Soft wheat flour

**Whole wheat flour (capacity alternates, generally, with other milling capacity)

(1) Does not include 7,000 cwts under construction at Albany, New York.

(2) Does not include 3,500 cwts under construction at Hastings, Minnesota.

(3) Does not include 2,500 cwts under construction at Buhler, Kansas, and 2,500 cwts at Inman, Kansas.

Similarly, the ten top wheat-durum-rye milling companies comprise only 30 percent of the total number of mills, but account for nearly 70 percent of the total milling capacity.

Top 10 Wheat-Durum-Rye Milling Companies (74)
(Also includes soft wheat and whole wheat flour)

Company	Mills	Capacity in cwts
The Pillsbury Co.	8	114,900 W
ADM Milling Co.	14	108,000 WD
Peavey Company	9	99,300 WDR(2)
ConAgra, Inc.	16	95,000 W
Seaboard Allied Milling Corp.	9	91,600 WDR(1)
International Multifoods	10	77,000 WDR
General Mills, Inc.	8	55,100 W
Cargill Flour Milling Division	4	50,000 W
Dixie-Portland Flour Mills	5	47,000 W
Nabisco, Inc.	4	40,000 W(3)
TOTAL	87	777,900 WDR

W -- Wheat Flour D -- Durum Products R -- Rye Flour

- (1) Does not include 7,000 cwts under construction at Albany, New York.
 (2) Does not include 3,500 cwts under construction at Hastings, Minnesota.
 (3) Does not include 2,500 cwts under construction at Buhler, Kansas, and 2,500 cwts at Inman, Kansas.

The distribution of wheat flour capacity by size groups shows that small mills with less than 1,000 hundredweights capacity per day account for 39 percent of the total number of wheat flour mills, but have less than 3 percent of the total milling capacity. Large mills with 10,000 or more hundredweights capacity per day equal only 12.5 percent of the total mills, but have nearly half of the total milling capacity.

Active Wheat Flour Capacity by Size Groups
(Includes soft wheat and whole wheat flour) (74)

Hundredweights per day	Number of Mills	Active Capacity
Under 200	43	4,776
200-399	34	9,625
400-999	23	13,870
1,000-4,999	65	169,320
5,000-9,999	57	385,060
10,000 & Over	32	459,540
TOTAL	254	1,042,191

The dry corn milling industry, like the wheat flour industry, has declined in the number of mills and increased in individual size during recent years. Four states, Kentucky, Tennessee, North Carolina, and Virginia, have 48 corn mills currently operating, which is nearly half of the total of 103 mills operated in the United States (74).

Many of the small mills located primarily in the South have a daily capacity of less than 500 hundredweight and produce white cornmeal for use in corn chips, tortillas, and other snack items (63). Mills in the corn belt region are generally larger, with an average capacity of 1,000 hundredweight per day.

Dry corn millers use most of the U.S. white corn to manufacture pearl hominy, grits, and cornmeal. They use yellow corn to produce corn flour and corn meal. Sizable quantities of corn flour are used by breakfast food manufacturers.

The control of insect pests in milling and processing plants presents many problems not encountered in bulk grain storages. There are many recesses and cavities in machinery where milled products tend to remain static during the normal operation. Insects are able to find these sites, deposit eggs in the product, and multiply. Eventually, eggs, larvae, pupae, and even adults find their way into the finished product.

The number and location of static points will vary with the kind of products being handled, as well as with age and design of equipment. Examples of such places are inside elevator and conveyer shafts, in and around sifters, purifiers, automatic scales, dust collectors, air ducts, vents, and other machines.

Although machinery is routinely dismantled for overhaul and repair, this is done far less frequently than necessary to prevent insect breeding. Through the years, it was learned that it is far more efficient to control insects only in specific machines rather than to apply an insecticide throughout the entire plant or to dismantle the machine for thorough clean-out.

B. State, Federal, and Industry Recommendations for Control of Insects in Stored Grain

General recommendations directed toward the control of pests infesting stored grain include at least some of the following subject areas:

1. An explanation of how insects affect the quality and market value of grain.
2. Factors that influence the development of insect infestations
3. Basic structural requirement for farm bins
4. Bin clean-up and treatment prior to grain storage
5. Application of protective treatments when grain is binned
6. Surface treatments after grain is binned
7. Inspection of grain during storage
8. Fumigation: Application methods and dosage recommendations
9. Aeration
10. Other information: Certification requirements, safety restrictions

Table 5. Carbon tetrachloride fumigant formulations and alternative formulations recommended by State for use on stored grain.

[illegible]

1/Added to grain as it is stored or turned
2/Abbreviations used: CD = carbon disulfide or carbon bisulfide, CT = carbon tetrachloride, EDC = ethylene dichloride, EDB = ethylene dibromide.

Table 6. States recommending the use of a carbon tetrachloride formulation on stored grains.

[illegible]

*Several states do not specify types of stored grains. A filled in box along this line indicates that the state in question makes recommendations for stored grains, the kinds of which may or may not be specified.

A summary of the pesticides recommended by individual states for use on stored grain is in Table 5. The kinds of cereal grains recommended for treatment by CCL₄-based fumigant formulations by each state is in Table 6.

Most state recommendations are designed to provide information for farmers who store grain on the farm. When directions for the treatment of commercial storages are included in state recommendations, they are usually of a general nature and applicable to both farm and off-farm storage. In some instances, state bulletins simply recommend that commercial storage owners contact a commercial fumigation company for either consultation or service for their treatment needs.

A composite example of state recommendations for the prevention and control of stored-grain insects is as follows:

1. Preventative Measures - Prior to filling bins (2 to 6 weeks)

- Clean up bins, aeration ducts, subflooring, augers, and other grain-handling equipment.
- Clean up spilled grain on the outside of the grain handling facilities
- Remove vegetation close to the bin or grain handling facilities
- Apply residual insecticides to grain storage facility (floor, ceiling, walls, ducts, and so forth).

The insecticides used primarily are:

	<u>per 2 gallon of water</u>
methoxychlor 50 pct WP	12 oz
methoxychlor 25 pct EC	1 qt
pyrethrins 6 pct EC	1-1/2 pt
malathion premium grade 57 pct EC	1/2 pt

-Apply chloropicrin to the space beneath the drying floor at the following rate:

Chloropicrin

32 oz per bin

2. Preventative Measures - During loading

-Apply protectants to the grain as it is being augered into the bin.

Protectants commonly used are:

Malathion - 1 pt (premium grade 57 pct EC) in 2-5 gal water per
1,000 bu

1 pct dust, 60 lb per 1,000 bu

Synergized pyrethrins - 1 qt (6 pct pyrethrins + 60 pct
piperonyl butoxide EC in 3-5 gal water
per 1,000 bu)

3. Preventive Measures - For stored grain

-Apply grain protectants to surface of stored grain.

Protectants commonly used are:

Malathion - 1 pt (premium grade 57 pct EC) in 2-5 gal water per
1,000 quart feed of grain surface

Synergized pyrethrins - 1 qt (6 pct pyrethrins + 60 pct
piperonyl butoxide EC) in 2-5 gal water
per 1,000 square feet of grain surface

Bacillus thuringiensis - 0.1 lb Dipel® WP per gal of water and
apply to top 4 inches of grain

4. Fumigation - after infestation

Fumigants* are applied to binned grain to eliminate established insect infestations. Best fumigation results are obtained by using the following guidelines:

- a. Level the grain. Remove or break up any crust on the grain surface.
- b. Seal all cracks, making the bin as airtight as possible.
- c. Fumigate on a still day, preferably when the grain temperature is higher than 15°C (60°F). Wind causes rapid leakage of the gas, and insect kill may be poor.
- d. Apply fumigants according to label directions. Most farm storages used the gravity penetration method. Apply the correct amount of liquid fumigant evenly over the surface of the grain. Cover the grain with a tarpaulin, especially if the bin is not full.
- e. The operator should stay out of the bin when applying liquid grain fumigants and wear appropriate respiratory protection. Phosphine formulations can be applied without wearing respiratory protection. Even so, two or more fumigators should work together (never fumigate alone).

*Fumigants, being highly toxic, are becoming restricted and certified applicators are required to apply some of them.

- f. Do not breathe vapors or fumes of any fumigant. Use a recommended gas mask equipped with a proper canister.
- g. Keep the bin closed for at least 72 hours. Do not enter the bin during or after fumigation until the fumes have been allowed to dissipate.
- h. When under fumigation, the storage bins should be locked and identified with "DANGER - KEEP OUT" signs to prevent entry and avoid accidents.
- i. Usually, it is safer, less expensive, and more effective to have your stored grain fumigated by a licensed and certified professional fumigator than to do it yourself. This applies especially to single upright bins containing more than 5,000 bushels. Flat storage structures present additional problems because of the relatively large grain surface area where insects congregate and fumigants quickly dissipate to ineffective concentrations.

Many state bulletins published prior to the mid-1970's contain dosage tables listing several types of liquid fumigant formulations and their recommended dosages for the treatment of various kinds of grain stored on the farm in steel and wooden bins. A composite example of such a table follows:

Amount of Fumigant to Apply per 1,000^{1/} Bushels of Stored Grain

Fumigant mixtures (percent)	Metal bin			Wooden bin (dosages apply to closed top wooden bins)		
	Wheat, rye	Shelled		Wheat, rye	Shelled	
		corn, oats, barley	Grain sorghum		corn, oats, barley	Grain sorghum
	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.
carbon tetrachloride (80) ^{2/} carbon bisulfide (20)	2-3	4-5	6-7	4	6	8
ethylene dichloride (75) carbon tetrachloride (25) ^{3/}	3.5	5	--	6	8	--
ethylene dibromide (5) ^{3/} ethylene dichloride (35) carbon tetrachloride (60)	2	4	6	4	7	8

^{1/}For lots of 500 to 1,000 bushels, use the same dosage as recommended for 1,000 bu.

^{2/}Apply when grain temperature is above 15°C (60°F).

^{3/}Apply when grain temperature is above 21°C (70°F).

Updated farm bulletins issued since 1975 generally reflect the current uncertainty as to which components of the various liquid fumigant mixtures will be approved or disapproved in the near future. As a result of this indecision, instead of listing commodity-dosage recommendations for specific liquid fumigant mixtures, the reader is advised to consult the fumigant label for this information (101). A recent state extension pamphlet on "Controlling insects in stored grain" (54) omitted recommendations for liquid fumigants entirely, but did provide a commodity-dose table for the use of aluminum phosphide, chloropicrin, and methyl bromide.

Federal guidelines for the control of insects in grain are included in the Stored-Product Pest Section of an Agriculture Handbook (current series number 584)

entitled "Guidelines for the Control of Insect and Mite Pests of Food, Fibers, Feeds, Ornamentals, Livestock, and Households" (118). This handbook is updated annually and is described as "a guide for entomologists and other research and extension workers rather than for use of individual users of insecticides." These guidelines encompass both bagged and bulk storage of grain in farm and commercial storages, with additional recommendations for the treatment of grain transporting and handling equipment.

General concepts of pest management in farm stored grain were also presented by USDA in a Farmers' Bulletin, Number 2269, issued in December 1979 (101). No similar federal publication of a general nature for the control of insects in commercial storage has been issued in the past 25 years. Numerous USDA reports published as Marketing Research Reports, AMS-Series or ARS-Series Reports and as articles in scientific journals have provided information on the efficacy of specific fumigant chemicals and on the use of specialized application techniques in commercial grain storages. Some examples are provided in the following references (29,85,96,97,99).

No USDA publications have been issued on the control of insects in flour mills since the 1958 Agriculture Handbook No. 133, "Insect Control in Flour Mills" (112).

Prior to establishment of the Federal Environmental Pesticide Control Act of 1972, recommendations among State, Federal, and industry sources often varied from specific label recommendations, particularly in the area of fumigant dosage for different cereal grains. Today, recommendations for the use of chemicals for control of insects in stored grain are essentially a compilation of material taken directly from the EPA registered product labels.

Although published recommendations generally reflect those listed on the registered label, rates of application often vary significantly between similar liquid mixtures of different manufacturers or formulators. Typical variations in the label recommended treatment rate for a common grain fumigant containing principally CCl_4 and CS_2 (80:20) are as follows:

	Gallons per 1,000 bu ¹ /			
	Bins Steel and concrete	Woodbins, shipholds	Flat storage	Box cars
Wheat/rye/barley	2-3	2-4	3-4	5
Grain sorghum	6-7	6-10	7-8	12
Oats/corn	4-5	4-7	5-6	8

¹/Source: Federal and State publications, manufacturer's product labels.

Variations in recommended dosages are based on sorption differences between commodities and the relative gas-tightness between structures. Other factors considered in determining dosage include: moisture content, grain temperature, air temperature, dockage and wind conditions. Most labels recommend that CCL_4 -based liquid fumigants be applied at grain temperatures of 15°C (60°F) or above. For mixtures containing more EDC than CCL_4 (75:25), dosage recommendations are slightly higher than for the CCl_4 - CS_2 mixtures and temperature limits are increased to 21°C (70°F) or above.

When appraising dosage rates commonly used in the grain industry for treating grain, several factors must be considered. First, unlike field applications of some insecticides, overdosages in the fumigation of stored grain are rarely observed owing to the high cost of the fumigant. Second, fumigation of feed grains such as sorghum or corn, particularly at rates of application

above 6 gallons per 1,000 bu, seldom occur in actual commercial practice. Official insect tolerances under the Special Grade "Weevily" for these grains are fairly lenient. They allow up to 14 insects in a representative sample (about 1 kg) if no species considered to be "live weevils" (Sitophilus spp, weevils; Callosobruchus maculatus, cowpea weevil; or Rhyzopertha dominica, lesser grain borer) are present. Furthermore, the cost of applying a liquid fumigant at these dosages or of turning the grain and applying a phosphine-producing fumigant would offer little advantage over accepting a "weevily" discount. Finally, it should be understood that many of the dosage recommendations for the various liquid fumigant formulations now registered with EPA are outgrowths of extrapolations from very limited performance data produced by either industry or by USDA research groups during the 30-year period from the mid-1930's into the mid-1960's. Dosages established for one formulation on one commodity in one type of storage were generally increased proportionally for formulations containing less active compounds, or when grains of greater sorptive capacity were treated, or when storage structures of increased surface areas or less tight construction were used. Many of the dosage schedules developed by this procedure were clearly unrealistic and were often used by the fumigant industry as selling points to show how one product could be used at substantially lower dosages than another and still achieve satisfactory results. Over the years, dosages that had little basis in fact or in practice were copied from label to label until they have now become an accepted part of most registered liquid fumigant labels.

The fumigation of U.S. agricultural commodities in export, particularly grains and oilseeds and their processed products, can fall under the jurisdiction of a large number of regulatory agencies. The number of these

agencies will vary with the location, but in most instances, they will represent Federal, state, and local governments. The number of agencies also will vary depending upon whether the fumigation is conducted at an inland site, in a railcar, at an export terminal, or on-board a ship. The minimum requirement for a fumigation will involve a state or EPA certified fumigator, the adherence to the EPA labeled uses of the fumigant, the pertinent allowable EPA and FDA residue tolerances, and the OSHA allowable levels of fumigant exposure. When the fumigation is conducted for the purpose of securing a phytosanitation certificate, the Animal and Plant Health Inspection Service (APHIS) of the USDA will have additional requirements, as will the FGIS of the USDA if the fumigation is made to remove a grade of "weevily" from the commodity. If the fumigation is conducted on-board a vessel, the U.S. Coast Guard has the final jurisdiction.

The U.S. Coast Guard regulations are found in USC Title 46 Ch. 1 Part 147-A, entitled "Interim Regulations for Shipboard Fumigation". These regulations are interim and quite liberal and allow for the fumigation of all types of cargoes on all kinds of vessels. Final regulations are presently being prepared.

In some instances, a fumigation of the export grain on-board vessels is called for in the contract between the foreign buyer and the U.S. grain merchant. When this occurs, the U.S. regulatory agencies do not become overly concerned or involved as long as the nation of the ship's flag and the importing nation request or accept the use of the particular fumigant. The fumigant, however, must be registered and labeled for use in the U.S. and it must be applied safely in accordance with the label directions. If the on-board fumigation is not called for by contract and if it is not prohibited by the ship owner, the nation of the ship's flag, or the contract, the U.S. grain merchant

may use fumigation as a means of removing the grade "weevily" from the grain. The inspection and establishment of U.S. grades on grain is the responsibility of the FGIS of the USDA.

Prior to September 29, 1976, the use of fumigants was covered by FGIS (then the Grain Division of Agricultural Marketing Service), AMS, GR Instruction 918-28, entitled: "Stowage Examinations for Shiplot Cargo." This regulation provided that if a lot (approx. 40-60,000 bu) of infested grain (weevily) is loaded on board a ship, it must be removed or fumigated in-place. This fumigation was only for the treatment of the infested lot and not for the total amount of grain in the hold or the hold itself. The fumigation was for a minimum of 12 hours.

In 1975, the USDA Agricultural Research Service (ARS) recommended to FGIS that this procedure of fumigating infested lots of grain onboard bulk-dry cargo ships be discontinued. It was suggested that such holds be filled with grain and the fumigant then applied at the proper dose for the amount of grain or hold volume. Thus, the fumigation was effected at sea or in-transit. On September 29, 1976, FGIS issued GR Instruction 916-8 entitled "Shipboard Fumigation," which allowed for this recommended procedure using the liquid fumigant 80:20 (CCl_4 and CS_2). On June 22, 1977, a revision of this instruction was issued, which extended the procedure to soybeans. On September 12, 1977, the instruction was again revised to allow for the use of aluminum phosphide fumigant formulations. In 1981, the procedure was extended to tanker-type vessels for a period of one year. (FGIS - Interim Policy - In-transit Fumigation of Grain Food Aboard Tanker-type Vessels, dated February 19, 1981). As the use of fumigants on-board vessels increased, the international community called this use of pesticides to the attention of the United Nations (U.N.).

Specifically, it was called to the attention of the Sub-Committee on Hazardous Cargoes of the Maritime Safety Committee (MSC) of the Inter-governmental Maritime Consultative Organization (IMCO) of the U.N. This Sub-Committee has addressed the use of certain pesticides on ships (MSC Circular 108) on several occasions (3); however, the specific subject dealing with the use of fumigant on ships had never been addressed. The Sub-Committee finally addressed the specific subject in April 1980 and again in December 1980. They approved a revision of their MSC/Circular 298 (formerly 108) entitled, "Recommendations for the Safe Use of Pesticides in Ships" (11). These recommendations are quite limited in scope and are largely administrative in nature.

C. Use of CCl₄ on Stored Grain and Milled Products

1. CCl₄ Formulators, Formulations, and Costs

Carbon tetrachloride is widely used as an ingredient of liquid fumigant mixtures. Because it is nonflammable, it reduces the fire hazards associated with the use of other insecticidal fumigant materials, such as carbon disulfide, and it also aids in their distribution through bulk grain. Liquid grain fumigants containing CCl₄ act upon storage pests in the vapor phase. Distribution of liquid fumigants applied to bulk grain is dependent on vaporization of the liquid, and because density of these vapors is greater than air, the vapors gravitate principally in a vertical direction downward through the grain.

Most fumigant mixtures containing CCl₄ are produced in the United States; however, the French firm, Rhone-Poulenc Phytosanitaire, and the Federal Republic of Germany company, Holsten Chemie, also market commodity fumigants containing CCl₄ for use in Western Europe.

Seven companies are identified by EPA (Federal Register Vol 45: 68551) as major domestic formulators of CCl_4 , and their annual production is reported at nearly one billion pounds. EPA also reports that 95 percent of the CCl_4 production is used in the manufacture of fluorocarbons; the remaining 5 percent is formulated into a variety of products including those of a pesticidal nature. Other sources (Chemical Economics Handbook, June 1980) indicate that four companies, Dow Chemical, Stauffer Chemical, Vulcan Materials, and Allied Chemical, produce nearly all of the CCl_4 manufactured in the United States, and their combined production capacity is reported at 768 million pounds annually. These companies report that only about 2 percent of production is used in formulating grain fumigants. The annual domestic consumption of CCl_4 in commodity and space fumigants is estimated at 20 million pounds.

About 56 companies are identified by EPA as having registered pesticide products containing CCl_4 ; however, nearly all of the commonly used fumigants with CCl_4 are formulated by only 10 companies:

- | | |
|----------------------|---------------------------------|
| 1. Dow Chemical | 6. Techne (Farmland Industries) |
| 2. Stauffer Chemical | 7. Industrial Fumigants |
| 3. Vulcan Materials | 8. Research Products |
| 4. Douglas-Chemical | 9. J-Chem |
| 5. Thompson Hayward | 10. Brayton Chemical |

One or more of the following compounds are mixed with CCl_4 by these formulators and the mixtures are sold for the purpose of fumigating bulk stored grain or as a spot treatment for milling or processing equipment.

- | | |
|------------------------|---|
| 1. carbon disulfide | 4. sulfur dioxide |
| 2. ethylene dichloride | 5. methylene chloride (probably discontinued) |
| 3. ethylene dibromide | |

Market shares for these types of liquid fumigant mixtures are estimated at ca. 45 percent of all grain fumigated. The following additional compounds are added to CCl_4 and sold as "liquid grain protectant."

1. pyrethrins
2. piperonyl butoxide
3. malathion
4. methoxychlor (sold as a residual fog for empty buildings, not for direct application to grain)

No commercial liquid grain fumigants are currently marketed that contain only CCl_4 . One product that contains CCl_4 and about 10 percent glacial acetic acid is registered as a grain fumigant, but its distribution is extremely limited and its principal marketing thrust is directed toward control of molds.

Three general types of liquid fumigant mixtures containing CCl_4 are marketed in the United States. Those in which CCl_4 is the major constituent, those in which EDC is the predominant compound, and those composed primarily of EDB. The most widely used liquid fumigant mixture for the treatment of bulk-stored grain belongs to the first type and consists of an approximate ratio (by volume) of 80 percent CCl_4 to 20 percent CS_2 , commonly known as "80:20." This mixture often contains small amounts of SO_2 as a warning gas and some CCl_4 - CS_2 formulas may contain from about 1 percent to 10 percent EDB. These "80:20" formulations contain approximately 10 lb of CCl_4 per gallon.

One common fumigant mixture in the second group contains about 75 percent EDC to 25 percent CCl_4 and is often referred to as "75:25." This formula is marketed both as a bulk-grain fumigant and as a spot fumigant for the

treatment of milling and processing equipment. Other mixtures in the EDC-predominant group may contain varying amounts of EDB and are generally packaged in 1- to 5-gallon lots for use in farm storage to improve control of insects near the grain surface. The third type of CCl_4 mixture that is predominantly EDB was marketed as a spot treatment for milling and processing equipment, but has now been generally discontinued in favor of a mixture of EDB and methyl bromide.

Each of these fumigant mixtures is used as supplied without the addition of water, oil, or other diluents. They are marketed in unit sizes of 1-, 5-, 30-, and 55-gallon cans or drums and in bulk tank lots of 1,000 gallons or more.

Manufacturers prices for CCl_4 have nearly doubled in the last decade to a level of about 20¢/lb. According to industry sources, however, this cost does not necessarily reflect actual trading price when the material is purchased in bulk quantities. Because CCl_4 is only used in a mixture with other fumigant compounds, the cost of utilizing CCl_4 for fumigation is more accurately reflected in the price of formulated liquid fumigant mixtures.

Although the cost of components in liquid fumigant mixtures that are predominantly CCl_4 differs from those mixtures that contain more EDC than CCl_4 , the retail prices of these fumigant mixtures are, for competitive reasons, essentially the same. Fumigant markets in the United States are divided into three zones. The Eastern zone includes states east of Ohio and south to the Gulf, the Western zone includes the mountain states and the Pacific Northwest, and the Middle States cover the center of the country from Minnesota to the Gulf of Mexico. In general, prices paid by country elevators are highest in the Western zone and lowest in the middle States. Fumigant prices in the

middle states are heavily influenced by Farmland Industries, who market their "Coop Brand" fumigants at price levels under those of other major brands and provide a rebate of about 5 percent to participating cooperatives (100).

	Average cost of fumigants per gal at country elevator	
	1-gal	5-gal
West	\$6.43	\$5.88
East	6.37	5.84
Middle	5.98	5.45
(Farmland)	(5.70)	(5.19)

2. Use of CCl₄ in On-Farm Grain Storage

Recent studies have indicated that relatively little of the grain stored on the farm is ever fumigated. In a 1978 survey of on-farm storage in Minnesota (46), only 8.2 percent of the wheat and 28 percent of the corn was reported to have received postharvest treatment. The infrequent use of preventative or remedial control measures taken by producers to maintain the quality of grain during storage was documented during the 1980 survey of insect infestation in farm-stored grain (106). A summary of actions reported by the producers interviewed is as follows:

Quality action indicated	Estimated percent frequency of use		
	Wheat	Corn	Oats
Chemical controls:			
Malathion	12.1	5.4	3.5
Fumigation	9.5	4.3	8.8
Dichlorvos (pest strip)	0.1	0.4	0
Nonchemical:			
<u>Bacillus thuringiensis</u> (moth control)	0	0.3	0
Physical actions:			
Aeration	6.2	21.3	1.4
Turning of grain	1.3	2.4	0.1
Raking or stirring grain surface	2.1	8.0	5.5

Application of the grain protectant, malathion, was the most frequently reported quality-maintenance action taken in farm-stored wheat; aeration was the most frequent action in corn, and fumigation was the principal action in oats. Grain reported by producers to have been fumigated was characterized as to type and composition of fumigant used, crop year treated, and density of dead insects present in the treated sample. The percentages for each type of fumigant identified as used in the three commodities surveyed were as follows:

Type of fumigant	Percent of identified responses		
	Wheat	Corn	Oats
Liquids	29.9	43.2	69.4
Phosphine	59.9	13.5	22.4
Methyl bromide	0	5.5	0
Chloropicrin	10.2	37.8	8.2

Fumigation was generally reported more than twice as frequently in older grain (crop year 1976) than in newer grain (crop year 1979), and most fumigations occurred during the second year of storage. More than one fumigation of the same grain was rarely indicated. Liquid fumigants were the predominant type used throughout all crop years in corn and oats, and phosphine was the principal fumigant used in wheat. Extensive use of phosphine in lieu of liquid fumigants was particularly evident during 1978 and 1979. Capacities of storages fumigated ranged from 1,500 to 36,000 bu and several of the larger storages were reported to have been fumigated by commercial applicators.

Most of the grain samples from bins identified as "fumigated" by the producers contained high densities of dead adult insects (106). Average densities and species involved were as follows:

Commodity	Average density (range)	
	Dead adult insects per 1,000 g	Principal species
Wheat	890 (32-2283)	<u>Tribolium</u> spp. and lesser grain borer
Corn	290 (106-428)	<u>Tribolium</u> spp. and <u>Sitophilus</u> spp.
Oats	1,449 (157-2923)	<u>Tribolium</u> spp. and sawtoothed grain beetle

Data obtained in producer interviews, together with the biological information developed during analyses of farm-stored grain, suggest the following characteristics:

1. Actions taken by producers to maintain the quality of grain during storage on the farm are minimal.
2. Less than 10 percent of the grain stored on the farm is fumigated during storage periods of 1 to 4 years.
3. CCl₄-based liquid fumigants are still the principal type used on oats and corn but have declined in use on wheat in favor of phosphine-producing fumigants.
4. High densities of dead insects present in grain reported as fumigated suggest that decisions to fumigate are often delayed until damaging levels of infestation have developed.

The fumigation method most often used to apply liquid fumigants containing CCl_4 in small farm-type bins is the application of the liquid material in a coarse spray over the grain surface. A bucket pump or garden sprayer adapted to produce a coarse spray by replacing the nozzle with a section of 1/4-inch pipe flattened on the end is generally used to apply liquid fumigants over the grain surface from outside of the bin. A less desirable method, still recommended on some fumigant labels, suggests applying the fumigant from a sprinkler can while walking over the grain surface in small bins of less than 4,000-bushel capacity. In larger bins, the volume of fumigant required for treatment, and the height to which it must be carried, dictates the use of power pumps capable of delivering the heavy liquid fumigants from ground level to the top of the bin. An alternate application method used in large bins in which the surface area greatly exceeds the grain depth involves the placement of 1- or 5-gallon cans of fumigation in a checkerboard fashion evenly throughout the bin. Each container is then emptied one at a time by holding the mouth of the container under the surface of the grain and dragging it back and forth.

Traditionally, most farm fumigations are carried out during late summer or early fall when the combination of warm grain temperatures and high insect activity provides conditions favorable for effective use of the fumigant. Under present marketing schemes, the length of time grain is stored on the farm is extended and sale of the grain may occur at any time during the year. This marketing practice creates situations where fumigants may be applied by the producer at any time during the calendar year to avoid costly discounts due to the presence of insects or to prevent outright rejection of the grain. Furthermore, fumigation to control extensive insect infestations may be required to continue eligibility for a farm storage loan under the Agricultural Stabilization and Conservation Service, Grain Reserve Program.

The amount of CCl_4 used annually for the fumigation of grain stored on the farm was estimated at about 300,000 \pm 50,000 gallons in a 1977-78 survey (45).

Category 1 - No reported use

- | | |
|-------------|--------------------|
| 1. Alaska | 7. Maryland |
| 2. Florida | 8. New Hampshire |
| 3. Guam | 9. Puerto Rico |
| 4. Hawaii | 10. Rhode Island |
| 5. Kentucky | 11. Vermont |
| 6. Maine | 12. Virgin Islands |

Category 2 - Insignificant amounts used

- | | |
|------------------|---------------------|
| 1. Arizona | 6. New Jersey |
| 2. Connecticut | 7. Washington, D.C. |
| 3. Delaware | 8. West Virginia |
| 4. Massachusetts | 9. Wyoming |
| 5. Nevada | |

Category 3 - Reported CCl_4 usages (gallons CCl_4)

- | | |
|-------------------------|--------------------------|
| 1. Arkansas - 1,290 | 14. Nebraska - 40,100 |
| 2. California - 6,330 | 15. New York - 3,000 |
| 3. Colorado - 19,500 | 16. N. Carolina - 16,000 |
| 4. Georgia - 25,000 | 17. N. Dakota - 17,170 |
| 5. Idaho - 25,750 | 18. Ohio - 12,390 |
| 6. Illinois - 27,500 | 19. Pennsylvania - 8,000 |
| 7. Indiana - 3,000 | 20. S. Carolina - 10,249 |
| 8. Iowa - 22,500 | 21. S. Dakota - 16,500 |
| 9. Louisiana - 5,263 | 22. Tennessee - 1,279 |
| 10. Michigan - 392 | 23. Utah - 400 |
| 11. Minnesota - 20,000 | 24. Virginia - 8,580 |
| 12. Mississippi - 1,600 | 25. Washington - 5,490 |
| 13. Missouri - 2,500 | |
| | TOTAL - 299,783 |

Category 4 - Unknown to date

- | | |
|---------------|--------------|
| 1. Kansas | 4. Oregon |
| 2. Montana | 5. Texas |
| 3. New Mexico | 6. Wisconsin |

Category 5 - No report received

Alabama
Oklahoma

Given the 300,000 (+50,000) gallons of CCl_4 marketed for on-farm stored grain, the American farmer paid \$1.68 million dollars (+\$280,000) to treat 75 million bushels of stored grain (using the application rate of 3 gallons per 1,000 bushels).

3. Use of CCl_4 in Off-Farm Grain Storage

The use of grain fumigants in off-farm storages is influenced by the source of the grain and the rate of turnover of grain at each storage location. For example, newly harvested grain received at a country elevator and passed directly on to a regional terminal would not be treated, but older grain delivered from farm storages later during the marketing year might be fumigated prior to its shipment to avoid "weevily" discounts assessed by regional terminals. The use of fumigants at regional elevators is highly variable within the grain industry but is generally predicated on the detection of infestation levels sufficient to cause the grain to be designated "weevily" when graded for shipment to the next point in the marketing system. The cost of fumigation has increased significantly during recent years, so the expenses involved preclude the use of this method of insect control as a routine management procedure for limiting the level of insect activity in grain. Fumigation is primarily a remedial procedure used to stop further development and damage of an existing insect infestation and to prevent the presence of live insects from causing the grain to be graded "weevily." It is rarely used in a preventive manner as a precaution against the buildup of insect populations in grain. The fumigation of grain is a time-consuming and expensive management tool that may be necessary only if the level of insect infestation impedes the further marketing of grain.

Two application techniques are generally employed in the treatment of elevator or silo-type storages. In the first method a portion of the total fumigant material is applied in equal stages during loading of the grain into the silo, for example, where the silo is 1/4, 1/2, 3/4, and completely filled. In this method some fumigation companies recommend applying one-fifth of the total fumigant dose at each of the first three levels with two fifths added after the silo is filled. A coarse spray is generally recommended for this application to limit vaporization of the liquid before it reaches the grain surface. In the second method the entire dosage is applied to the grain surface after the silo is filled. Penetration throughout the grain mass is slower by this method, but tests have demonstrated that adequate distribution can be achieved in well-sealed silos. These two basic methods of silo treatment with liquid fumigants have been used in the grain industry for over 50 years.

As grain elevators began to increase in both numbers and size, many of the larger elevator companies installed bulk storage tanks with capacities of 1,000 to 5,000 gallons to permit purchase of tank-car quantities of liquid fumigants. These storage systems are equipped with pumps that lift the fumigant to surge tanks located above the rows of silo storages. A network of pipes radiating from the surge tank to points along the overhead gallery provides direct access for application of the liquid fumigant into each tank. Following introduction of solid aluminum phosphide formulations in the early 1960's, further development of the liquid fumigant application systems declined. During recent years the use of phosphine in off-farm storages has continued to replace the traditional liquid fumigants in situations where the grain can readily be transferred from one bin to another, a step that enables the uniform application of an aluminum phosphide formulation into the grain. Thus, distribution of the fumigant gas and biological efficacy are achieved throughout the grain mass.

One of the most difficult types of grain storage to fumigate effectively is large flat storage in which the total grain surface area greatly exceeds its depth. Application of liquid fumigants in flat storage requires the use of pressure tanks, or more commonly, portable fumigant pumps capable of lifting the liquid from ground level to the overhead area above the grain at delivery rates of 5 to 15 gallons per minute. During application, the nozzle of the delivery hose may be held just below the surface of the grain and moved in a zigzag pattern or the liquid may be "sprayed" in a nearly solid liquid stream onto the grain surface. A supplied-air respiratory protective unit or a self-contained breathing apparatus must be used in this type of operation. Two applicators are generally employed in this operation; one actually applies the fumigant and the other is located in an "outside" position where he can observe the applicator at all times and render assistance if necessary.

Fumigations with liquid mixtures containing CCl_4 are not necessarily restricted to a set time period within a storage year, but are generally predicated on need and low grain temperature that could prevent adequate vaporization and distribution of the fumigant materials. Fumigations at country elevators often begin in late summer or early fall when grain previously held in storage may be moved out to accommodate incoming fall crops. Grain temperatures are often at maximum levels at this time and adult insect activity may also be more readily evident. Each of these factors, high grain temperature and active insect stages, contributes positively to the overall efficacy of fumigation. Fumigations at subterminal or terminal locations may occur throughout the entire marketing year, with temperature of the grain being the limiting factor.

The limited use of fumigants in commercial storage is reflected in the results of an informal survey of 50 commercial elevators in Kansas made during

1978 by the Extension Department of Kansas State University (unpublished data). Data obtained in the survey indicated that only 12.0 percent of the wheat, 2.3 percent of the sorghum, and 1.7 percent of the corn stored and handled by these elevators during 1978 were fumigated. Two types of fumigants were used in these treatments, phosphine and CCl_4 -based liquid fumigants containing one or more of the following compounds: CS_2 , EDC and EDB. The percentage of each grain treated with each type of fumigant was as follows:

	<u>Percent fumigated</u>	
	<u>Liquid mixtures</u>	<u>Phosphine</u>
Wheat	19	81.0
Sorghum	54.2	45.8
Corn	70.3	29.7

Recent spot checks of selected elevators in Montana, Wyoming, Oregon, Indiana, and Kansas indicate that the percent of grain handled and stored each year that is fumigated is highly variable among the various types of grain stored and among individual grain companies (102). Among all grains treated, about 75 percent was wheat, 25 percent was corn, and less than 1 percent was barley. No sorghum or oats were reported to have been fumigated with conventional grain fumigants. The percentage of grain treated at individual elevator locations ranged from only 4 percent to as much as 80 percent for wheat, from no treatment to only 3 percent for corn, and from no treatment to 12.5 percent for barley. Nearly 80 percent of the fumigated wheat and corn was reported to have been treated with phosphine and 20 percent with liquid fumigants containing CCl_4 . The only barley treatments reported were with liquid fumigants. One elevator location reported that 77 percent of the wheat, 39 percent of the sorghum, and all of the small volumes of oats and

barley that they handled were treated with a mixture containing about 92 percent CCl_4 plus 0.27 percent pyrethrins and 2.65 percent piperonyl butoxide. This material is marketed as a "liquid grain protectant" and is applied as the grain is being put into storage. The formulator-distributor of this material and other similar "liquid grain protectants" containing pyrethrins, malathion, and CCl_4 reports that sales of these products are limited primarily by the overall cost of the formulations.

4. Use of CCl_4 in Flour Mills and Processing Plants

Current flour mill sanitation programs were described by Smith (90) as being composed of three elements: (1) A housekeeping program that includes standardized procedures to clean equipment and plant areas, (2) judicious use of pesticides in conformance with applicable Federal requirements, and (4) a prevention inspection program on incoming raw materials, mill equipment, the facility itself, and outbound transportation equipment. Fumigants identified by Smith (90) as now used routinely in spot treatments of mill equipment included one or more of the following materials: Carbon tetrachloride, ethylene dibromide, ethylene dichloride, and methyl bromide.

A spot fumigation is defined as the application of low volatile fumigants into enclosed units of milling equipment for the purpose of controlling insects (90). Spot fumigations usually employ portable applicators that reduce the time required to fumigate and accurately measure dosages to be applied to the individual pieces of equipment. This treatment procedure is a highly specialized operation, especially tailored to specific pieces of milling equipment, and developed primarily within the milling industry itself. Based on a survey questionnaire (41) sent to industry trade associations, 5 of 6

associations report that their members spot fumigate, generally on a monthly basis. A summary of their responses to questions concerning spot fumigation is as follows:

Size of the trade association and percent of industry represented.

Master Brewers	3600	100 pct
National Macaroni Mfg.	64	90 pct
Millers National Federation	65	80 pct
Assoc. of Operative Millers	1800	75 pct
Corn Miller Federation	22	70 pct
Rice Millers Assoc. (no response to specific question)		

Question: Does your industry use "spot" fumigation:

Five of six industries use spot fumigation. (Macaroni Mfg. does not as reported by their association)

Question: Frequency of spot fumigation.

Majority reported monthly. Rice Millers reported weekly.

One reported - didn't know.

Question: Who does the spot fumigation?

Majority do their own - others hire or contract.

Question: Can spot fumigation be replaced by four general fumigations?

Majority say no. Millers National Federation report that 37 percent of their members say yes, 50 percent say no; 12 percent no experience to render judgment.

Question: How much more costly will general fumigation be over spot?

Majority estimate 10X, a few feel six to eight times.

Question: Can machinery be modified so as to not require spot fumigation?

Those who responded say no.

Question: How much more costly would be a routine cleanout as compared to spot fumigation?

Some don't know, others estimate 5X - others already use routine cleanout in program.

Question: Assume no spot fumigation is available, what options?

Far more labor in sanitation program.

Before applying a spot fumigant, the area to be treated is closed, feed stock cut, the machine run until empty, then pipes are tapped with a rubber mallet to remove as much stock as possible. Static stock is not cleaned as this tends to help confine the fumigant inside the machine. A predetermined amount of fumigant is introduced into the machinery through specific application points.

Many plants have the application points well identified and built-in as a permanent part of the machine so fumigant can be quickly and expeditiously introduced into critical points. In multi-storied factories, special tubing is sometimes installed so that the point of injection is in the most appropriate place, usually where static stock accumulates and insects develop. Spot fumigation is done when the plant is "down," often over the weekend. Room and/or mill is placarded.

After fumigation mills are normally aired before start-up. This aeration is done by opening outside doors, turning on process ventilation and the general ventilation. Mills are usually "opened" several hours to one day before operations are resumed. Individuals opening the mill would normally wear masks.

The frequency of spot fumigation varies considerably, depending on product handled, type and age of equipment, geographic location of the factory and many other factors. Older plants located in warm climates would require more

frequent spot fumigation than modern plants located in cool climates. Spot fumigation is not a substitute for good manufacturer procedures, nor is it a replacement for general sanitation. It is a part of the total quality assurance program for the plant and/or industry. Many plants schedule approximately 12 spot fumigations per year.

There are only three basic fumigant mixtures containing CCl_4 currently marketed for spot treatment of milling machinery with specific dosage recommendations for individual pieces of equipment such as elevator boots, rolls, sifters, and conveyors. Composition of these mixtures is as follows:

Percent/weight

1. 32 pct CCl_4 , 59 pct EDB, 9 pct EDC
2. 59.9 pct CCl_4 , 20.5 pct EDB, 17.6 pct EDC
3. 30 pct CCl_4 , 70 pct EDC

Directions for use of these products are characterized as follows:

FIRST. Run machines as dry as possible before shutting down. Excessive stocks prevent proper gassing. Clean out machine if necessary.

SECOND. Close openings to machines to stop air currents. Tie off sifter stockings. Close off machines by stuffing openings with sacks or paper. Seal packout bins by tying one-third of a bag of flour up on tubes.

THIRD. Fill a sufficient number of 32-oz prescription bottles to treat all units. Distribute filled bottles to convenient points in building before pouring any fumigant.

FOURTH. Apply fumigant directly from the bottles into the machines according to the dosage table. Treat machinery on bottom floor first and work upward in building. At the end of 24 hours, open doors and windows to air out building and open machines.

Examples of dosage and points of application recommended for individual pieces of equipment are as follows:

MINIMUM DOSAGE TABLE

Machinery unit	Application point ^{1/}	Amount (fluid ounces)
Elevator boots	Nearest opening above	6
Elevators heads	Inside at top	12
Roll stands (in each side)	Nearest opening above	6
Reel and purifier conveyors	Along entire length	6
Reel and purifier inspouts	Nearest opening above	6
Sifters	Nearest opening above	6
Conveyors (6-8 inches)	Along length	2 per ft (Min.-8 oz)
Conveyors (10-16 inches)	Along length	3 per ft. (Min.-16 oz.)
Dust trunks	Points along length	12
Spouts	Top opening	1 to 2 (per ft length)
Storage bins	On walls at top	6 per/ 100 ft ³ of space
Dusters (Bran and shorts)	At top opening	12

^{1/}Fumigation should be done on weekends or holiday when building is empty of people.

No precise figures are available that document the actual amount of milling and processing equipment. Development Planning and Research Associates (DPRA) in their report on CCl₄ to EPA (10) estimated that about 5 percent or 55,000 gallons of liquid fumigant mixtures containing ethylene dibromide were used

annually in the spot treatment of flour mills. The Millers National Federation (MNF) (73) reported that a poll of their members placed the estimated annual use of CCl_4 at 107,854 pounds. If each of these estimates is converted into the spot fumigant mixture containing 59.9 percent CCl_4 , 20 percent EDB, and 20 percent EDC, each 6 oz application of this mixture would contain 3.6 oz of CCl_4 and each 12 oz application 7.2 oz of CCl_4 . Applying these rates of application to the 254 flour mills in the United States (74) at a frequency of 14 times per year, the DPRA estimate of 55,000 gallons of a EDB- CCl_4 mixture would provide 3.6 or 7.2 oz of CCl_4 for between 153 and 307 pieces of equipment in every single mill in the United States, 14 times a year. The MNF estimate of 107,854 pounds of CCl_4 would treat between 60 and 120 pieces of equipment in each mill 14 times per year. No data are available to confirm or deny such widespread use of CCl_4 in flour mill treatments. Such use estimates of CCl_4 become even more questionable when considered against industry reports that a mixture of 70 percent EDB and 30 percent methyl bromide (with no CCl_4) is the preferred fumigant or spot treatment in mills.

5. Use of CCl_4 on Export Grain and Oilseeds

Export elevators and warehouses are located at most of our major sea ports, major rivers, Great Lakes and the Gulf of Mexico. Some major ports include New Orleans, LA, and Houston, TX, on the Gulf of Mexico; Norfolk, VA, Baltimore, MD, and Philadelphia, PA, on the Atlantic Ocean; Long Beach, CA, and Portland, OR, on the Pacific Ocean; and Duluth, MN, and Chicago, IL, on the Great Lakes. Appendix I lists U.S. export elevators, ownership addresses, and cites storage and outloading capacity.

Efforts to determine utilization of fumigants in general, let alone CCl_4 , in export facilities met with little success. Most major U.S. grain exporting companies are closely held and will not readily provide any information regarding their operations. Only one confidential response was received and was essentially as follows:

1979-80

Weevilcide	89,635 gallons (52 pct CCl_4)
Detia	10 cases
Phostoxin	85 cases
Dawson 37	150 pounds
(30 pct EDB, 70 pct methyl bromide)	
Dawson 73	180 gallons
(70 pct EDB, 30 pct methyl bromide)	

1980-81

Weevilcide	97,495 gallons (52 pct CCl_4)
Malathion	5,040 gallons
Detia	1 case
Phostoxin	13 cases

This list represents only the chemicals that were purchased by Central Purchasing Department and applied by the company's own people. It does not include fumigants applied on ships, those used by contract fumigators, nor any locally purchased material.

The number of ships that have sailed with an in-transit fumigation called for by a contract is not known. Contract conditions are not public information; however, it is believed that the number of ships in this category in the last 5 years is at least 1,000. Importing nations that are known to have required fumigation in some years, if not in all years, are the People's Republic of China, Brazil, Peoples Republic of Poland, Chile, and Nigeria. In early 1980, it was estimated that at least one hold on more than 1,200 ships had been fumigated in-transit in the last 4 to 5 years (32). Information provided by two major distributors of fumigants for shipboard use for presentation to IMCO in 1980 lists vessels treated (Appendix II). In the early fall of 1981, the Foreign Agricultural Service of the USDA estimated that the number of vessels having received in-transit fumigation exceeded 1,000 during 1975 through 1981 (69).

6. Use of CCl₄ on Imported Commodities

A carbon tetrachloride-carbon disulfide (80:20) mixture is used as a regulatory treatment at ports of entry for conifer and other seeds infested with certain insect species among the chalcid wasps and seed midges. These phytophagous species are readily transported in seed from one country to another. When seed arrives in the U.S., it is inspected at a plant quarantine station and infested shipments are treated.

The only treatment currently prescribed in the APHIS Treatment Manual is fumigation according to the following schedule (111).

T203(7):

- a. For Megastigmus spp., Plemeliella abietina, Resseliella spp., and other Cecidomyiidae.

Carbon disulfide - carbon tetrachloride at normal atmospheric pressure for 24 hours at 70 degrees F. or above. (1:5 mixture by weight; 1:4 mixture by volume -- Vertifume® or equivalent. Dosage 5 lbs carbon disulfide and 25 lbs carbon tetrachloride, respectively, per 1,000 cubic feet (9.0 ml of mixture per cubic foot).

Load limit 50 percent of chamber volume. Seeds to be in small lots, 24 lbs or less, spread thinly. Fan circulation for first 4 hours. Aerate in well ventilated area minimum of 24 hours.

Exceptions: Cedrus spp. - Dosage 3.5 lbs and 17.5 lbs, respectively, per thousand cubic feet (6.3 ml per cubic foot).

Seed may not be tolerant, reduced germination may occur.

Of the total volume of seed imported only about 335 kilograms valued at about \$3,500.00 are fumigated annually (113). These fumigations utilize only 4.5 liters of the fumigant 80-20 per year valued at \$5.95.

7. Estimates of the Annual Agricultural Usage of CCl₄:

No data are available that directly quantify the total amount of CCl₄ used annually in the fumigation of agricultural products and handling facilities. Two estimates, each using different approaches, have been constructed. The first estimate (Table 7) is based on the reported CCl₄ production of 1 billion pounds/year (EPA) and the estimated use of 2 percent of production (20 million pounds) in the formulation of grain fumigants. This estimate assumes the manufacture of four basic liquid fumigant formulas and calculates the total gallons of mixed fumigants that could be developed from 20 million pounds of CCl₄.

Table 7. Estimated annual use of carbon tetrachloride (CCl₄) in the formulation of liquid fumigant mixtures.

Production:

1 billion pounds/year (EPA)

Percent of production to fumigant use:

$$2\frac{1}{2}\% \times 1 \text{ billion} = 20 \text{ million pounds}$$

Common Liquid Fumigant Formulas:

20% CS₂-80% CCl₄ contains ca 10 pounds of CCl₄/gal mixture or .7564 gal of CCl₄/gal of mixture

73% EDC-27% CCl₄ contains ca 3.125 pounds CCl₄/gal mixture or .2364 gal of CCl₄/gal of mixture

20% EDB-60% CCl₄ contains ca 8.2 pounds of CCl₄/gal mixture or .6203 gal of CCl₄/gal of mixture

59% EDB-30% CCl₄ contains ca 4.7 lbs of CCl₄/gal mixture or .3555 gal of CCl₄/gal of mixture

20 Million pounds of CCl₄ Formulated as Follows:

(95%) 20% CS ₂ -80% CCl ₄	19,000,000 lbs at 10 lbs/gal = 1,900,000 gals of mixture
(4.4%) 73% EDC-27% CCl ₄	880,000 lbs at 3.125 lbs/gal = 281,600 gals of mixture
(0.5%) 20% EDB-60% CCl ₄	100,000 lbs at 8.2 lbs/gal = 12,195 gals of mixture
(0.1%) 59% EDB-30% CCl ₄	20,000 lbs at 4.7 lbs/gal = 4,255 gals of mixture
(100%)	20,000,000 lbs
	2,198,050 gals of liquid fumigants containing CCl ₄

¹/Source: Chemicals Economic Handbook, June 1980.

The second estimate is constructed in three separate steps. The first step (Table 8) develops an estimate of liquid fumigant use based on the average stocks of grain available on farms and off farms for treatment. Off-farm stocks include all grain at mills, elevators, warehouses, terminals and processors. The percentage of grain stocks fumigated with all types of fumigants and the percentage of fumigated stocks treated with liquid fumigants were based on producers' information developed during a survey of farm stored grain (106), spot checks of elevators (102), and personal communications with commercial pesticide applicators, distributors, and formulators (105). The second step (Table 9) calculates the amount of liquid fumigant mixture included in the total gallonage obtained in step one that contains EDB in the mixture. This step utilizes the amounts of EDB reported by the four major formulators as used in the manufacture of liquid fumigants containing from 1.2 to 7.4 percent EDB in the mixture (105). The third step (Table 10) calculates the amounts of CCl_4 used in the limited formulation of liquid mixtures containing 20.5 percent and 59 percent EDB for the treatment of milling machinery.

Data from each step are combined in Table 11 to provide a summary of CCl_4 use in three categories: bulk grain fumigants formulated without EDB, bulk grain fumigants formulated with EDB, and liquid mixtures for the treatment of milling machinery.

The first estimate places the annual use of CCl_4 at 20,000,000 pounds formulated into 2,198,050 gallons of liquid fumigant mixtures. The second estimate shows the combined use of CCl_4 to be 13,521,178 pounds formulated into 878,895 gallons of fumigant mixtures without EDB, 483,308 gallons with EDB, and 15,145 gallons of mill machinery fumigants for a total 1,377,348 gallons. Estimates based on reported CCl_4 production are ca. one-third higher than

Table 8. Estimated annual use of carbon tetrachloride (CCl₄)-based liquid fumigants in bulk stored grain.

Commodity Location	Average stocks (1,000 bu)	Estimated percent fumigated		Estimated percent fumigated CCl ₄ -based fumigants	Bushels fumigated (1,000 bu)	Bushels fumigated (1,000 bu)	Average dosage gal/1,000 bu	Total gallons CCl ₄ -based fumigants
		(all fumigants)						
<u>Wheat</u>								
On Farm	1,200,000	10%		30%	120,000	36,000	3	108,000
Off Farm	1,500,000	25%		30%	375,000	112,500	2	225,000
<u>Corn</u>								
On Farm	4,600,000	5%		70%	230,000	161,000	4	664,000
Off Farm	1,700,000	10%		50%	170,000	85,000	3	225,000
<u>Oats</u>								
On Farm	400,000	9%		70%	36,000	25,200	3	75,600
Off Farm	90,000	9%		70%	8,100	5,670	2	11,340
<u>Sorghum</u>								
On Farm	200,000	5%		70%	10,000	7,000	5	35,000
Off Farm	400,000	5%		50%	20,000	10,000	4	40,000
On Farm	6,400,000	6.2%		57.9%	396,000	229,200	3.76	862,600
Off Farm	3,690,000	15.5%		37.2%	573,100	213,170	2.35	501,340
TOTALS	10,090,000	(9.6%)		(45.6%)	969,100	442,370	(3.08 gals)	1,363,940

Table 9. Estimated gallonage of fumigant formulated with ethylene dibromide (EDB) and carbon tetrachloride (CCl₄).

Company	Total EDB formulated pounds	Percent EDB in formula	Number pounds	Pounds EDB per gal	Gallons of liquid fumigant mixture
A	73,000	1.2	44,530	.1522	292,575
		5.0	28,470	.6418	44,360
B	57,000	5.0	57,000	.6418	88,813
C	33,000	7.2	9,900	.92	10,761
		6.6	19,800	.87	22,758
		5.0	1,650	.65	2,538
		7.4	1,650	.95	1,737 ^{1/}
D	16,000	6.6	8,000	.87	9,195
		5.0	8,000	.65	12,308
TOTALS	179,000		179,000	(.37)	485,045

^{1/}Product contains EDB, but no CCl₄.

Table 10. Estimated annual use of ethylene dibromide (EDB) and carbon tetrachloride (CCl₄) in mill machinery fumigants.

Pounds of EDB formulated	Percent of EDB in formula	Pounds of EDB per gallon of mixture	Percent of CCl ₄ in formula	Pounds of CCl ₄ per gallon of mixture	Gallons of CCl ₄ per gallon of mixture	Total gallons of EDB-CCl ₄ mixture	Gallons of CCl ₄ in mixture
40,000	20.5	2.8	60.0	8.2	.62	14,286	8,857
8,000	59.0	9.32	30.0	4.7	.35	859	301
48,000						15,145	9,158 ^{1/}

^{1/}9158 gallons of CCl₄ x 13.22 lbs/gal = 121,069 lbs of CCl₄.

Table 11. Summary of the estimated annual use of carbon tetrachloride (CCl₄) in the formulation of liquid fumigant mixtures.

Gallons of Liquid Fumigant Mixtures:

Total gallons fumigant mixture in grain stocks (Table 8).	1,363,940
Total gallons fumigant mixtures formulated with EDB (Table 9).	<u>485,045</u>
Total gallons of liquid fumigants without EDB	878,895
Total gallons mill machinery fumigants (Table 10)	15,145

Calculated Gallons of CCl₄ in Fumigant Mixtures:

878,895 gallons of CCl ₄ mixtures without EDB	
95% in mixtures containing .7564 gal of CCl ₄ /gal of mixture =	631,556
4.9% in mixtures containing .2364 gal of CCl ₄ /gal of mixture =	10,181
0.1% in mixtures containing .82 gal of CCl ₄ /gal of mixture =	<u>809</u>
Total gallons of CCl ₄	642,546

485,045 gallons of CCl₄ mixtures with EDB
 - 1,734 gallons of mixture with EDB and without CCl₄

483,308 gallons of mixtures with EDB and CCl ₄	
60.6% in mixtures containing .775 gallons of CCl ₄ /gal of mixture =	226,746
30.6% in mixtures containing .754 gallons of CCl ₄ /gal of mixture =	111,606
6.6% in mixtures containing .81 gallons of CCl ₄ /gal of mixture =	25,882
2.2% in mixtures containing .636 gallons of CCl ₄ /gal of mixture =	<u>6,844</u>
Total gallons of CCl ₄	371,078

15,145 gallons of CCl ₄ mixtures for mill machinery.	
94.3% in mixtures containing .62 gallon of CCl ₄ /gal of mixture =	8,857
5.7% in mixtures containing .35 gallon of CCl ₄ /gal of mixture =	<u>301</u>
Total gallons of CCl ₄	9,158

Pounds of CCl₄ in Fumigant Mixtures:

642,546	gallons of CCl ₄ in mixtures without EDB.
371,078	gallons of CCl ₄ in mixtures with EDB.
<u>9,158</u>	gallons of CCl ₄ in mixtures for mill machinery.
1,022,782	gallons of CCl ₄ in all mixtures x 13.22 lbs/gal = 13,521,178
	pounds of CCl ₄ .

estimates based on grain stocks, treatment percentages, and component formulations. Although the use of grain fumigants is expected to vary somewhat from year to year, it is reasonable to assume that the range of CCl_4 usage falls somewhere between these two estimates.

Each of these estimates is significantly lower than the estimate reported by DPA (10) of 28.2 million pounds of CCl_4 or that listed by Holtorf and Ludvik (50) of 25 to 32.6 million pounds of CCl_4 .

One of the major problems in developing use estimates of fumigant chemicals is the failure to recognize that any single component estimate must be developed in terms of its combination with other components, so that the combined materials do not understate or overstate the gallonage of mixtures likely to be formulated and applied. For example, the Millers National Federation (MNF) report that their members use an estimated 107,854 pounds of CCl_4 and 290,000 pounds of EDB per year in treatments of milling machinery (73). If the 107,854 pounds of CCl_4 were formulated on the basis of the EDB and CCl_4 estimates shown in Table 10 (94.3 percent in mixtures containing 8.2 pounds of CCl_4 and 2.8 pounds of EDB per gal of mixture and 5.7 percent in mixtures containing 4.7 pounds of CCl_4 and 9.32 pounds of EDB per gal of mixture) it would provide 13,711 gallons of EDB- CCl_4 mixtures containing 46,919 pounds of EDB and the stated 107,854 pounds of CCl_4 . By subtracting the 46,919 pounds of EDB in the mixtures from the 290,000 pounds of EDB reported by MNF, ca. 243,000 pounds of EDB remains to be applied in the form of EDB-methyl bromide mixtures. However, the only company formulating the EDB-methyl bromide mixture places its annual use of EDB in this mixture at ca. 150,000 pounds or 93,000 pounds less than the usage estimated by MNF.

Overestimates of fumigant use are also evident in EPA Position Document 2/3 on EDB. EPA estimates that 630,000 pounds of EDB are used annually in the fumigation of grain storage facilities, and another 465,000 pounds are used for the control of insects in flour milling equipment. By using the calculations developed in Table 9, the 630,000 pounds of EDB used in grain storage would be formulated into ca 1.7 million gallons of fumigant mixture containing ca. 1.3 million gallons of CCl_4 or 17 million pounds. Additionally, if 1/4 of the 465,000 pounds of EDB used in milling equipment was formulated into EDB- CCl_4 mixtures proportionate to those shown in Table 10, and the remaining EDB was used in EDB-methyl bromide mixtures, it would still provide an estimated 29,280 gallons of EDB- CCl_4 mixtures containing ca. 387,000 pounds of CCl_4 . Thus, a total of nearly 17.4 million pounds of CCl_4 would be required just to account for the amounts of EDB estimated in the Position Document as used in the fumigation of bulk grain and milling equipment. The 17.4 million pounds of CCl_4 represents 87 percent of the estimated annual production of 20 million pounds (Table 7) and from 54 to 69 percent of the 25 to 32.5 million pounds estimated by Holtorf and Ludvik (49). Data obtained from the pesticide industry, grain handlers, and producers indicate that no more than 35 percent of the liquid fumigants, whether marketed as bulk grain fumigants, spot fumigants or mill machinery fumigants, contain EDB.

A more realistic estimate of EDB usage is obtained by combining data calculated in Table 3 and 4 as follows:

Fumigant type	Percent EDB in formulations	Pounds of EDB used	Gallons of EDB-CCl ₄ mixtures
Bulk grain	1.2 to 7.4	179,000	485,045
Mill fumigants	20.0 to 59.0	48,000	15,145
EDB-methyl bromide ^{1/}	30.0 to 70.0	147,600	—
Total		374,600	500,190

^{1/}Industry source: Estimated annual use of EDB in combination with methyl bromide.

In this estimate the 500,190 gallons of fumigant mixture produced from the 227,000 pounds of EDB estimated as used in bulk grain and mill fumigants represents about 35 percent of the total amount of liquid fumigant mixtures applied to grain stocks (Table 8) and to milling machinery (Table 10).

Two general conclusions are drawn from the data developed in this section. First, separate estimates for EDB and CCl₄ use are often not compatible with each other in terms of their combined use in mixed formulas of liquid fumigants. Second, use estimates based on production data, grain stocks, marketed formulas, recommended dosages, and information obtained from the pesticide industry, grain handlers, and producers indicate that EPA's RPAR actions against EDB and CCl₄ significantly overestimate the use of these compounds for the fumigation of stored grain and milling equipment. The consequence of this overestimation of fumigant use manifests itself in an equally overstated risk, particularly in terms of application and dietary exposure.

D. Alternatives for the Control of Insects in Stored Grain and Milled Products

1. Pest Control Materials Currently Registered

a. Phosphine

(1) Formulations

Solid aluminum phosphide formulations that release phosphine gas on exposure to moisture in the atmosphere or in the grain are marketed in the United States by three companies: Degesch America, Inc., Weyers Cave, VA, product trade name Phostoxin®; Bernardo Chemicals Ltd., El Monte, CA, product trade name Gastoxin®; and Research Products Company, Salina, KS, product trade name Detia Gas® EX-B. Phostoxin and Detia Gas have been marketed in the U.S. for about 15 years. The Gastoxin product has been introduced into the U.S. market during the past year.

Aluminum phosphide products are used throughout the world for the disinfestation of a wide variety of stored products. Industry sources suggest that an estimated 70 percent of total sales of aluminum phosphide fumigants is for grain and processed cereal products, 20 percent is for stored tobacco, and the balance is for stored peanuts, dried fruits, tree nuts, and other miscellaneous food products. In August 1979, phosphine fumigation was accepted by the Japanese Ministry of Agriculture as the official treatment requirement for phytosanitary certification of United States hay exports to Japan.

Aluminum phosphide formulations are no longer merely an alternative to CCl_4 -based liquid fumigants for the treatment of off-farm storage; they have now become the predominant fumigant in this market. Furthermore, the extensive use of phosphine in lieu of liquid fumigant

mixtures in farm storages during recent years (106) suggests that this material is making inroads into this market, particularly in the treatment of wheat.

Phosphine producing fumigants are not considered a viable alternative to liquid fumigants containing ethylene dibromide or to ethylene dibromide-methyl bromide mixtures for the spot treatment of milling equipment because of the high volatility of phosphine and the problems encountered in retaining adequate concentrations of the gas within the equipment for sufficient time to make it an effective treatment.

Substituting general plant fumigations with phosphine-producing materials for spot treatments with liquid fumigants is discussed under the methyl bromide section.

Formulation and packaging of phosphine products marketed in the United States for grain treatment are as follows:

Phostoxin (Degesch America, Inc.)

Formulation: Aluminum phosphide 55 percent
inert ingredients 45 percent

Package size: (1) Resealable aluminum flasks of 500 3-gram round tablets
(2) Aluminum tubes of 30 3-gram tablets
(2) Resealable aluminum flasks of 1,660 0.6-gram pellets
(3) Prepac® strips each containing 165 pellets
and packaged 4 strips in a sealed can

Gastoxin (Bernardo Chemicals Ltd.)

Formulation: Aluminum phosphide 57 percent
inert ingredients 43 percent

Package size: (1) Resealable aluminum flasks of 500 3-gram tablets
(2) Resealable aluminum flasks of 1660 0.6-gram pellets

Detia (Chemische, Fabrik Dr. Freyberg, F. R. Germany)

Formulation: Aluminum phosphide 57 percent
inert ingredients 43 percent

Package size: (1) Sealed cans containing 15 porous paper bags
(sachets); 34 grams of granules per bag
(2) Resealable aluminum flask of 500 3-gram tablets
(3) Resealable aluminum flask of 1660 0.6-gram pellets

Fumtoxin (Peoples Republic of China)

Formulation: Aluminum phosphide 57 percent, inert ingredients
43 percent.

Package size: (1) Resealable aluminum flask of 500 3-gram tablets
92) Resealable aluminum flask of 1660 0.6-gram pellets

Costs of these materials are a product of the unit size and volume purchased. The price to end users for a 3-gram tablet is about 9 to 10-1/2¢ per tablet and 2 to 2-1/4¢ per 0.6-gram pellet.

(2) Application Techniques

Aluminum phosphide formulations are solid materials, which in the presence of atmospheric moisture break down and liberate a gas, phosphine (hydrogen phosphide). If the liberation of hydrogen phosphide occurs too rapidly, an explosive mixture can result. To control the rate of release of hydrogen phosphide, aluminum phosphide is formulated with ammonium carbonate or aluminum stearate and calcium oxide.

As with other fumigants, aluminum phosphide formulations must release phosphine, thereby acting upon storage pests in the vapor or gas phase. Distribution of phosphine gas in bulk grain is generally dependent on the placement of pellets or tablets throughout the grain bulk, or where overhead leakage is minimal (such as shipholds) the material may be placed directly on the grain surface.

Recommended dosages for the various phosphine-producing fumigants are similar. The actual amount of phosphine involved in the treatments

may vary considerably depending on whether tablets or pellets are used and the type of storage structure. Because phosphine distribution is not materially affected by sorption difference between various commodities, application rates are based primarily on types of storage structure as follows:

<u>Type of Storage</u>	<u>Grams Hydrogen Phosphide/1,000 bu</u>
Upright concrete or metal silos	24-150
Metal-farm type bins	40-180
Flat storage	55-180
Box cars	50-180
Barges	(Same as land-based structures)

The basic method of applying phosphine-producing fumigants in silo type storages is by the use of an automatic dispenser that drops the solid material into the grain as the grain moves on a conveyor belt into storage. Flat storages are generally fumigated by manually inserting the solid material into the grain by using a hollow probe. In some instances where overhead areas of shallow depth storages are particularly gastight, the material may be broadcast over the surface of the grain and "stepped" into surface of the grain.

The time involved and the number of workers used to apply phosphine fumigants vary with the type of structure treated. For silo fumigations the time of application continues until the bin is filled and is, therefore, dependent on the handling capacity of the elevator. For flat storage, or in any space where people are applying the fumigant, the time available for application is limited by the available time between exposure of the fumigant formulation to air and the initial evolution of the phosphine. There is normally a delay of 1 to 3 hours after exposure to air before the toxic gas is produced.

For silo fumigations the number of applicators is generally limited to one or two persons to fill, monitor, and adjust the automatic dispensing equipment. When the aluminum phosphide is applied manually in flat storage fumigations, a number of applicators may be required to ensure that application of the material is completed before significant amounts of the phosphine are evolved.

A recent technique developed for application of phosphine to bulk stored grain involves the placement of bags or sachets of an aluminum phosphide preparation into pockets of a paper or cotton "bag blanket", that is then rolled out over the surface of the grain (91). When first used, the blankets were prepared outside of the bin, thus reducing the labor and time required to apply the material. Now, the "bag blankets" are prepackaged at the factory and are ready to use. Retrieval of the "dust-like" remains in the sachets following release of the phosphine is also made easier by use of the "bag blankets". Treatments of large masses of grain (such as ship holds) by this method require tightly sealed storage structures and extended periods of exposure time to allow for penetration of the phosphine through the grain mass.

(3) Precautionary measures

No protective equipment is required if the fumigant is applied within the period before the gas evolution begins, other than gloves, which are to be worn if the tablets or pellets are actually handled. Approved gas masks with proper canisters are recommended to be available in case of emergency, or if fumigation takes longer than planned.

(4) Post-fumigation activities

It is recommended that proper gas detectors be used to monitor atmospheres before reentering the fumigated area. After aeration is complete, residues of the fumigant formulation are removed from where

the fumigant was applied externally to the grain mass, such as when sachets or prepacks are taped to boxcar walls or placed on the surface of grain. The residues are removed to the outside, where they are placed in water containing detergent, to cause decomposition of any active ingredient that may remain.

b. Methyl bromide

Methyl bromide is a gaseous fumigant marketed as a liquid under pressure in cylinders or cans. It has been used since the 1930's as a means of disinfestation of soil, warehouse and food plants, boxcars, processed commodities, and bulk grain. It is the principal fumigant used for the postharvest treatment of tree nuts, raisins, and dry edible beans. Methyl bromide is also used as the official quarantine treatment for a wide range of food and nonfood commodities by many countries throughout the world.

The development of methyl bromide as a bulk grain fumigant began in Germany in the early 1930's (75). By using a recirculation method developed for the application of methyl formate, methyl bromide was released through piping into the base of a hoppers storage tank, propelled by a blower upward through the grain mass, and then returned by a pipe attached to the top of the bin that extended back to the blower. This method of recirculating methyl bromide in silo-type storage was first introduced in the United States just prior to World War II, but did not receive widespread interest until the late 1940's and early 1950's, when the method was adapted for the treatment of cottonseed storage tanks (83), oil storage tanks (29), and liberty cargo ships (84). The use of methyl bromide in bulk grain reached its

peak in the late 1950's when provisions of Public Law 518 (effective July 22, 1955), The Miller Amendment, limited the amount of pesticide residue permitted on food crops. The initial legal residue tolerance established for methyl bromide was 50 ppm inorganic bromide for most grain crops. Thereafter, most of the methyl bromide market in off-farm bulk grain storage was replaced with phosphine-producing fumigants. Methyl bromide is rarely used for the treatment of farm stored grain, except by commercial applicators.

Methyl bromide is formulated either as 100 percent methyl bromide or with 0.5 to 2.0 percent chloropicrin as a warning agent. It is packaged in 1- to 1.5-lb cans and in cylinders ranging from 50 to 1,500 pounds each. The unit cost of methyl bromide ranges from \$0.91/lb in large quantities to \$1.50/lb in quantities of less than 50 pounds. The average cost is estimated at \$1.25 per pound.

Methyl bromide is applied to bulk grain by utilizing existing grain aeration systems to push or pull (recirculate) the fumigant through the grain. Distribution of the gas is accomplished either in a single-pass method in which the fan is operated for the time calculated to produce one complete air change within the stored commodity and the introduction of the fumigant is prorated over this period, or a provision is made to bring the air-gas mixture drawn or pushed through the grain mass back to the fan. This recirculation may be accomplished by using a flexible return duct or by connecting an adjacent tank to serve as a return duct. The fan is operated for the time estimated to produce two or more air changes within the commodity (94). Following fumigation periods of 24 to 48 hours, the aeration system is used to

exhaust the fumigant from the treated commodity. Both upright tanks and flat storage are treated by variations of this forced distribution principle.

Methyl bromide is applied directly from the cans or cylinders in which it is purchased and, because of its relatively high vapor pressure, no additional propellant is required. Scales for weighing the methyl bromide cylinders are generally used to measure the amount of material used. Rates of application are generally in the range of 2 to 4 pounds per 1,000 ft³ of storage space, which is equivalent to about 2.5 to 5 pounds per 1,000 bushels of grain depending on the amount of air space present above the grain surface.

Reestablishment of methyl bromide as a dominant fumigant in the treatment of bulk-stored grain would require modification of existing aeration systems to permit forced distribution of the gas and a reappraisal of the tolerances now established for inorganic bromide residues that severely restrict the use of methyl bromide.

More frequent general fumigations with methyl bromide or phosphine have been proposed as an alternative to spot fumigation of milling equipment. Opportunities to exercise this option are limited. Many plants are not well suited for general fumigation because of their location or design. Many milling operations extend between floors and even several floors, and also between buildings. In a general fumigation, the gas must be confined in and around the entire structure or facility. Within the same building there usually are offices, warehouses, boiler plants, repair shops, and other rooms. Few plants are designed so these facilities can be easily separated or excluded

from a general fumigation. These areas will be needlessly exposed to a toxic pesticide, or they will be excluded by extensive and expensive sealing.

A general fumigation is a highly questionable alternative because far more people could be exposed to dangerous pesticides. For example, some facilities are located in downtown, or near, metropolitan areas near low cost housing, next to major highways, freeways, and even less traveled city streets. Gas released or generated as a fumigant dissipates slowly through walls, ceilings, floor drains, dust collectors, windows, and doors. Once fumigation is completed the remaining gas is exhausted into the atmosphere. If the plant were situated in an open prairie or desert, no serious problems would be foreseen; however, exhausting large quantities of fumigants into a densely populated area would rightfully be questioned by air pollution control officials. This procedure could be extremely hazardous, particularly if the scheduled gas release time coincided with a temperature inversion.

There are some who maintain that spot fumigation is done so frequently that this procedure tends to expose the public to hazardous pesticides, and they offer as an alternative a general fumigation, possibly four times a year, in place of the more frequent spot fumigations. Precise figures are not available to illustrate the differences between the volume of a machine treated with a spot fumigant and the volume of the whole plant if it were fumigated. Obviously, the machine is only a small fraction of the total mill or plant. Far fewer people risk exposure to fumigants when spot

fumigation is used compared to a general fumigation because: (1) smaller quantities of fumigants are handled and used, and (2) the chemical is introduced directly into machinery or equipment, which helps confine the gas to the critical points.

General fumigation is costly and hazardous. Millers surveyed, placed the cost for general fumigation at seven to ten times more expensive than for spot fumigation. Both methyl bromide and phosphine may react with or be absorbed by some plastics, copper, brass, rubber, and other items commonly used in the milling and food processing industry. Copper is the standard metal used in brew-kettles, and is an essential component for inline sensors, fire alarms, switches, control panels, computers, and many other types of electronic equipment, including electric motors. These must be sealed off or enshrouded from the general fumigant.

Manufacturers of aluminum phosphide warn users:

"Pure hydrogen phosphide (phosphine gas) is practically insoluble in water, fats, and oil and stable at normal fumigation temperatures. It does not enter into irreversible chemical reactions with the fumigated commodities. It may, however, react with certain metals, particularly copper, copper compounds such as brass, silver, and gold, and cause corrosion, especially at high temperatures and humidity. Precautions should be taken to protect materials made from such compounds including some types of copying paper and undeveloped film."

Manufacturers of methyl bromide likewise warn fumigators about unanticipated "side reactions."

Methyl bromide is a highly efficient and effective space fumigant that may be used with confidence to protect a wide variety of stored commodities from damage by insects or rodents. Wide experience with the product, however, has demonstrated that certain materials, particularly those containing reactive sulfur compounds, should not be exposed to methyl bromide.

The most common reason for avoiding fumigation of a material with methyl bromide is the "off-odor" caused by a reaction of the fumigant with certain sulfur compounds. Such odors usually persist indefinitely and are virtually impossible to remove. It is a wise fumigation practice, therefore, in the event of uncertainty about the presence of reactive sulfur compounds in the material to be fumigated, to conduct a trial fumigation of a small quantity of the material in question.

Another reason for avoiding fumigation with methyl bromide is the "sorptive" quality or "solvent effect" of certain materials, which can reduce the concentration of methyl bromide in the fumigated area to the point of ineffectiveness.

Still other reasons for caution with methyl bromide include phytotoxicity (that is, toxicity to growing plants), destruction of seed viability, the possibility of illegal residues, and the rapid deterioration, after fumigation, of such commodities as fresh fruits and vegetables.

The following is a partial list of materials that experience has demonstrated should not be exposed to methyl bromide:

1. Foodstuffs

- a. Iodized salt stabilized with sodium hyposulfite.
- b. Full fat soya flour.
- c. Certain baking sodas, cattle licks (that is, salt blocks), or other foodstuffs containing reactive sulfur compounds.
- d. Fresh fruits and vegetables.

Note: Overdosing, overexposure, or repeated fumigation of any food or feedstuff commodity should be avoided. In the event a repeated fumigation is necessary, the commodity should first be analyzed for inorganic bromide residues to determine whether the proposed treatment may result in residues that exceed tolerances established by the EPA. Also, special care must be exercised to assure that methyl bromide fumigation of such commodities as animal feeds, flour, dried eggs, dried figs, dried milk, nuts, meat, and meat products will not result in above-tolerance bromide levels.

2. Seed, Bulbs, and Plants

- a. Seeds and bulbs to be used for planting.
- b. Nursery stock and other living plants.

3. Pets (all pets, including fish and birds.)

4. Rubber Goods

- a. Sponge rubber.
- b. Foam rubber, as in rug padding, pillows, cushions, mattresses, and some car seats.
- c. Rubber stamps and other similar forms of reclaimed rubber.

5. Furs
6. Horsehair
7. Feathers (especially in feather pillows)
8. Leather goods (particularly white kid or other leather goods tanned with sulfur processes)
9. Woolens (extreme caution should be used in the fumigation of angora woolens. Also, some adverse effects have been noted on woolen socks, sweaters, shawls, and yarn.)
10. Viscose rayon (also, those films or fibers that either contain or have been manufactured by a process that uses carbon disulfide.)
11. Vinyl
12. Paper
 - a. Silver polishing papers.
 - b. Certain writing paper and other papers cured by sulfide processes.
 - c. Photographic prints and blueprints stored in quantity.
 - d. "Carbonless" carbon paper.
13. Cellophane
14. Photographic chemicals ("darkroom" chemicals, but not cameras or film)
15. Rug padding
16. Cinder blocks
17. Mixed concrete

18. Mortar (including mixtures of mortar or soil used for chinking log cabins)

19. Charcoal

Note: Methyl bromide is readily absorbed by charcoal or other organic materials. This may not only contaminate such materials, but may reduce the concentration of the gas in the fumigated area to the point of ineffectiveness.

Some commercial fumigators are reluctant to fumigate newer facilities, because of the liability problems, or they demand a "hold harmless" clause in their contract so the milling company assumes the risk. Mistakes can be extremely expensive in a general fumigation.

c. Chloropicrin

Chloropicrin is a nonflammable liquid fumigant that vaporizes to a gas on exposure to air. It is added to other fumigants as a warning agent and is marketed in pressurized and nonpressurized containers as a space, grain, and soil fumigant. Throughout much of its history, chloropicrin has been referred to as a tear gas, but due to its relatively low vapor pressure (23.8 mm Hg @ 25°C and 10.37 mm. Hg @ 10°C) and corrosive action on metals, it has been commonly marketed in glass bottles and applied as a liquid fumigant. To facilitate handling the large amount of chloropicrin required in flour mills and large bulk grain storages constructed during the 1950's, chloropicrin was formulated with methyl bromide or pressurized with methyl chloride in metal cylinders and discharged as a fine mist from which the

chloropicrin volatilized. The development of the pressurized cylinders enabled fumigators to apply chloropicrin directly to bulk grain by the recirculation method. Cylinders that could be pressurized with air just before application were also developed. Recirculation of chloropicrin was used extensively in flat storages throughout the mid-prairie states during the mid-1960's (95).

Chloropicrin is currently marketed in cans of 1 to 32 pounds each and in cylinders of 70 to 375 pounds each. Recommended dosages range from 2-1/2 lb/1,000 bu for wheat to 4-1/2 lb/1,000 bu for sorghum. One recommended method of applying chloropicrin to bulk grain is by the introduction of a prorated portion of the total dosage directly into the grain stream as the grain is loaded. It is further recommended that an aliquot of chloropicrin be applied for each 1/2 foot or less of grain depth. When applying chloropicrin in this manner, a full-face gas mask with appropriate canister would be required.

Unit cost for chloropicrin ranges from \$3.00 to \$5.00 per pound depending on the quantity and package size purchased.

Because chloropicrin is heavily sorbed by grain during treatment, long periods of aeration are required to remove the odor and resulting tear-gas effect following fumigation. Concentrations as low as 1 ppm produce intense irritation of the eyes. Continued exposure may cause serious lung injury. These adverse properties make chloropicrin an unlikely alternative to any other fumigant material now available for treatment of bulk-stored grain.

d. Other Organic Compounds Formulated with CCl_4

Several volatile organic compounds now formulated with CCl_4 are sufficiently toxic to be effective as insect fumigants. These compounds include ethylene dichloride, ethylene dibromide, carbon disulfide, and sulfur dioxide. Each compound has properties that limit its usefulness as an independent grain fumigant material. Carbon disulfide and ethylene dichloride are flammable and require dilution with CCl_4 for safety, sulfur dioxide is water soluble and highly corrosive, and ethylene dibromide has a boiling point of 131°C (269°F), which slows its vaporization and penetration into the grain.

The future use of these materials in grain fumigant mixtures in the absence of CCl_4 or a suitable nonflammable substitute is questionable.

e. Grain Protectants

Only two chemical insecticides, malathion and synergized pyrethrins are currently approved for direct application to grain for the purpose of controlling or limiting insect development. These insecticides are generally applied in the form of diluted sprays to the grain as it moves into a storage bin on a conveyor belt. After the binning operation is completed and the grain surface is leveled, a surface dressing of the insecticide is applied to help prevent insects from entering the grain or feeding on the surface.

Synergized pyrethrins are limited in their effectiveness, expensive, often in short supply, and they offer a comparatively short period of protection.

Malathion is an effective treatment against most beetle species that attack stored grain, but loses its effectiveness rapidly as the moisture content and temperature of the stored grain increase. A recent survey of malathion resistance among several species of stored-grain insects found in 14 states indicated acute and widespread resistance in the Indianmeal moth and red flour beetle and some resistance among lesser grain borer and Cryptolestes spp. (17,42).

The principal problem with grain protectants is their limited use. In a survey of over 8,000 farm bins across 27 states (106), biologically active levels of malathion were detected on only 14.6 percent of the wheat, 8.2 percent of the corn, and 4.2 percent of the oats examined. Nearly half of the samples in which malathion residues were analyzed contained concentrations under 2 ppm, a level generally considered to be only marginally effective. Nevertheless, when malathion was present in the grain, both the incidence of insects and the density (number) of insects per kilograms of grain was less. The most frequent storage pest found in malathion-treated grain was the Indianmeal moth, particularly in corn. Other insect pests occasionally found in treated grain included lesser grain borers, Tribolium spp. and flat grain beetles, Cryptolestes spp.

f. Miscellaneous Materials

(1) Dichlorvos: Strips of polyvinyl chloride (PVC) impregnated with dichlorvos are recommended to control adult grain insects mostly in the overhead space of binned grain using 1 strip/1,000 ft³ of space. Dichlorvos is not approved for direct application to the grain.

(2) Methoxychlor: This relatively nontoxic analogue of DDT has been recommended for more than 30 years as a surface spray for treating the inside and outside of bins prior to loading them with grain. Its present day use is believed to be minimal.

Methoxychlor is not approved for direct application to grain.

(3) Diatomaceous earths: These silica materials are highly abrasive to insect cuticle, and under certain conditions they can be effective against storage pests. Their use is extremely limited owing to a variety of negative factors, including: Increased machinery wear, reduced grain flow, altered appearance of the grain, dustiness, and possible adverse affect on grain grade.

(4) Bacillus thuringensis: A commercial formulation of this bacterium has been approved for use in stored grain and soybeans. This material is mixed with the surface 4-inch layer of grain either by adding to the last grain as it is augered into the bin or, after the grain is binned, by applying it to the surface of the grain and mixing the top 4-inch layer with a scoop or rake. The treatment is effective against the moth species that infest grain, but it will not control weevils or other beetle pests.

2. Alternatives to Registered Fumigants and Protectants

a. Physical controls

(1) Inert dusts. Inert dusts have some value in protecting stored grain from insects. Some of the materials evaluated in the United States in addition to diatomaceous earth include: Silica aerogels, magnesium oxide, and activated clays. These materials control by

abrasive action, with their activity related to high surface area per gram of substance. The major disadvantages to inert dusts are: 1) Damaging machinery through abrasion, 2) increasing risk to fire or explosion, 3) causing lung damage to workers, and 4) reducing the test weight. The insecticide qualities of inert dusts, even when mixed with protectants like malathion, are outweighed by the disadvantages.

(2) Heating and Cooling. Temperature is an important factor in the growth and reproduction of most stored-grain insects. The optimum temperature for the common storage insect is ca. 28°C (23), and by lowering this temperature the storage time of the grain can be increased because the activity of the insects is decreased. A grain temperature of 15°C will prevent most storage insects from completing their life cycles.

Heating the grain to temperatures above 40°C will be unfavorable to most insects, but a temperature of 60°C is required to kill the insects. Some difficulties associated with the heating, or especially the cooling, of grain to control insects is the insulation effect of grain fines (particles of grain and foreign materials). It is difficult to get a uniform temperature within a bin of grain (even with the stir/aerator bins). Grain fines concentrate in pockets within the grain mass according to the spouting equipment and the insects will migrate to these areas and cause "hot spots."

(3) Drying. As most insects require grain moisture values of 9-18 percent for favorable reproduction, the drying of grain to levels below 9 percent would be a method to retard insect infestation. The drying would also be conducive to microbial control, as drying is a practical method of controlling respiration.

(4) Irradiation and Sonication. There have been several studies on the use of various radiant and sound energy to control stored-grain insects (24). This type of control generally causes sterility or induces lethal genetic mutations in the insect. At this time, irradiation and sonication methods are uneconomical to use compared to the use of fumigants.

(5) Hermetic Sealing. Hermetic sealing is the process of making the storage structure completely airtight. The principle of normal grain respiration would decrease the oxygen (O_2) in the air and increase the carbon dioxide (CO_2), causing death of storage insects and micro-organisms. However, the difficulty of making a grain bin airtight, plus trying to control normal moisture migration without forced air, has kept the success of this idea to a minimum. Also, this technique promotes the growth of anerobic bacteria.

(6) Cleaning and Sanitation. Removing all stages of insects from the recesses and cavities in machines where milled products tend to remain static during operation can be done by dismantling the machinery including transfer pipes and elevator shafts. The cost to each facility will vary depending on the product handled and the design and layout of equipment. Those who replied to a survey questionnaire estimated the cost of such cleaning to be five to ten times more costly than spot fumigation. The cost will be inflationary and be passed on to the consumer because frequent dismantling of machinery for cleaning will not increase the efficiency or productivity of the facility.

b. Chemical Controls

(1) Modified atmospheres

The atmospheric gas mixtures that have been approved for the control of stored-product insect pests in processed agricultural commodities (except fresh meat) and that were exempted from the requirement of a tolerance (Federal Register 45, 223, Nov. 17, 1980, 75663 and Federal Register 46, 112 June 15, 1981, 32865) are as follows:

CO₂ (40-60%); balance-air

N₂ (98%); balance O₂ and other normal components of air

O₂ (≤1%), CO₂ (9-11%), N₂ (84.5-89%), Argon (1%), and

H₂ + CO (1.5%)

The modified atmosphere method of treatment involves the continuous introduction of CO₂, N₂, or generated atmospheres into a storage at a rate sufficient to achieve and then maintain displacement of the normal atmosphere for a specific period of time necessary to cause the death of storage pests. Several industrial gas companies have obtained label registration for the various gases and generating equipment required and are attempting to develop their commercial use. Further research is needed to develop practical application techniques and to document the economic feasibility of these nonproprietary products as a means of disinfestation and storage maintenance of stored grain and milled products.

(2) Protectants and Residuals. Other than malathion, pyrethrins, and methoxychlor, there are currently no protectant chemical alternatives. Researchers are studying some "candidate" protectants that show varying degrees of success, as follows (44):

(a) Acephate (O,S-dimethyl acetylphosphoramidothioate).

Acephate has been used to control insects attacking vegetable and orchard crops. It has wide activity against insects and low acute toxicity; however, Watters (119) found it to be generally less effective than malathion.

(b) Bay SRA 7660 (phenylglyoxylonitrile oxime (O)-O,O-dimethyl phosphorothioate). This material has been compared to malathion against the common grain insects Rhyzopertha dominica, Tribolium confusum, and so forth, in 1976 by McDonald and Gillenwater (71). Their findings demonstrated that malathion was superior or equally toxic at 10 ppm. However, in the field, Bay SRA 7660 was more effective at 10 ppm than malathion.

(c) Chlorpyrifos-methyl (Reldan®) (O,O-dimethyl-O-(3,5,6-trichloro-2-pyridyl)phosphorothioate). This material has shown considerable success in controlling stored-grain insects. It has been applied with synthetic pyrethrins in a dust or spray at 10 ppm and was very effective in controlling insects in stored corn (122). LaHue (62) used chlorpyrifos methyl as a protectant and could control Sitophilus spp. for 12 months at 3 ppm. LaHue also demonstrated that this material was more effective than malathion, phoxim, or tetrachlorvinphos in controlling Sitophilus spp. in sacked grain.

(d) Pirimiphos-methyl (Actellic®) (O-[2-(diethylamino)-6-methyl-4-pyrimidinyl] O,O dimethyl phosphorothioate). This successful candidate has been tested by many researchers (31,55,60,61,77). All of the research has shown that pirimiphos-methyl is effective in controlling stored-grain insects. One month after treating test grain at 5 to 20 ppm, pirimiphos-methyl killed all of the test insects exposed for 1 hour. In a 12-month small-bin storage study, pirimiphos-methyl at 7.8 ppm was more effective than malathion (10.4 ppm) against Tribolium spp.

Preliminary experiments indicate that pirimiphos-methyl is highly toxic to five malathion-resistant strains of Plodia interpunctella. In addition, the malathion-resistant strains showed no cross resistance. This chemical could be considered as a potential replacement for malathion.

(e) Diuretic Agents. These chemicals function by disrupting the water retention ability in insects. Dr. R. Beeman tested some known mammalian diuretic agents on insects and five of the agents produced acute toxicity to O. surinamenis.

(f) Fenitrothion (O,O-dimethyl O-(3-methyl-4-nitrophenyl) phosphorothioate). Out of 16 organophosphate insecticides, fenitrothion is the most effective against Tribolium spp. (66). Fenitrothion has also been proved effective against Sitophilus spp. and other stored-grain insects. Dosages of 2 and 4 ppm were effective for 6 to 10 months.

(g) Iodofenphos (O-(2,5-dichloro-4-iodophenyl)O,O-dimethyl phosphorothioate). Both Girish and others (39) and LaHue (59) tested the protectant potential of iodofenphos compared to malathion for control of various species of stored-product insects. Iodofenphos had a fairly high contact toxicity to Sitophilus oryzae, Tribolium castaneum, Trogoderma granarium, and Rhyzopertha dominica compared to malathion at similar dosages and also was comparatively more persistent on concrete surfaces and jute bags (39). A dosage of 1.5 g/m³ was sufficient to control the insects for 1 month. LaHue (59) also concluded that iodofenphos was a promising grain protectant on hard red winter wheat, shelled corn, and sorghum at rates of 5 to 20 ppm against S. oryzae.

(h) Methacrifos. This is an organophosphorus insecticide (O-2-methoxycarbonylprop-1-enyl O,O-diethyl phosphorothioate)

of low mammalian toxicity that shows promise against several species of storage insects including the increasingly malathion-resistant Sitophilus spp. and Tribolium spp. (86). Residues of 5 to 15 ppm protected the grain for several months with no adverse influence on grain germination or on baking quality, taste, or odor of subsequent cereal products. Methacrifos is also reported as suitable for spray application on surfaces.

(i) Methyl Phoxim ((O)-O,O dimethyla-cyanobenzylideneamino-oxy phosphorothioate). Methyl phoxim has been shown to be effective at 5 ppm for 2 to 9 months against four species of stored-grain insects (1). In the study, methyl phoxim was compared to malathion, and at 10 ppm it performed as well as malathion against R. dominica. Residual studies indicated that after 30 days 10 percent was left on 20-percent moisture sorghum, 3 percent on 20-percent moisture wheat, and 33 percent on 20- percent moisture corn. Lower moisture levels indicated longer persistence of methyl phoxim.

(j) Pyrazoline Derivatives. According to Kramer and McGregor (58), pyrazoline derivatives may be useful as protectants for stored products. They concluded that TH-6041 (N,3-bis(4-chlorophenyl)-4,5-dihydro-1 H-pyrazole-1-carboxamide) and TH-6042 (N,3-bis(4-chlorophenyl)-4,5-phenyl-1 H-pyrazole-1-carboxamide) have some potential to protect stored commodities against three beetle species but not against T. confusum or O. surinamenis. TH-6042 appeared to have the greatest potential to minimize the development of beetle and moth populations.

(3) Insect Growth Regulators (IGR). The potential of IGR's as stored-product insecticides has been investigated for several years. Insect growth regulators control the insects by preventing the larva from developing into an adult (juvenile hormone) or disrupting the natural moulting process (ecdysone).

A number of synthetic insect growth regulators that have shown promise are available (44):

-Methylene dioxyphenyl ether of 6,7-epoxygeraniol prevented pupation of Trogoderma granarium (56).

-Dimilin® analog of methylene at 1 ppm prevented progeny development of Sitophilus spp. (72).

-Methoprene (isopropyl (E,E)-11-methoxy-3,7,11-trimethyl-2,4-dodecadienoate) reduced populations of Sitophilus spp. at 2 to 10 ppm and prevented normal development of Plodia interpunctella (2).

-Pyridyl and phenyl ether, analog of juvenile hormone, gave varying degrees of control (57).

(4) Natural Products. A number of studies are being conducted on the potential of natural products as grain protectants (44). Some of these products are: 1) Mineral and vegetable oils, 2) capric acid, 3) sorbic acid, 4) hot peppers, 5) cypress and mahogany leaves, and 6) ferns.

Wendell Burkholder (25) has shown that significant mortality can be obtained on Sitophilus spp. by using 10 ml/kg vegetable oils (cottonseed, soybean, corn, and peanut) on wheat. Sorbic acid has known ovicidal properties for several species of stored insects. Florence Dunkel (33) demonstrated that a 0.3-percent mixture of

sorbic acid suppressed the reproduction of Sitophilus spp., that is 85 percent in the laboratory and 42 percent in the field.

(5) Grain Fumigants. The activity in researching candidate fumigants has been slower than that in grain protectants (44). Generally, the ideal candidate fumigant would be more host-specific and less hazardous to the applicator than those now in use.

Soles and Harein (92) reported the relatively high fumigant toxicity of N-(alpha-methylacetonitrile)-morpholine and acetate of dimethyl 2,2-dichloro-1-hydroxyvinylphosphonate to four species of stored-product insects. The candidate fumigants 1,2,3-tribromopropene, ethylenimine, and crotyl bromide (86 pct 1-bromo-2-butene and 14 pct 3-bromo-1-butene) were also more toxic at LD₉₅ than carbon tetrachloride to stored-product insects (47). Cooper and Gillenwater (27) reported that five of the six candidate fumigants included in their testing program were more effective than methyl bromide against Tribolium confusum, Lasioderma serricorne, and Attagenus megatoma. The level of effectiveness of all six indicated that further evaluation as potential grain and space fumigants was warranted.

Preliminary laboratory research by Gillenwater and Leesch (38) indicated that a candidate fumigant identified as TD-5-32 (A13-27428) was ca. 600 times more toxic than methyl bromide to adult T. confusum (44). Leesch continued his studies (65) to report that two perfluorinated alcohols (CCRL-489 and CCRL-583) proved to be more toxic than methyl bromide to adult T. confusum, L. serricorne, and full-grown larvae of A. megatoma when the fumigations were conducted in free space. Fumigations in wheat at low temperatures (13°C) reduced their toxicity below that of methyl bromide.

There is no known alternative to the use of "80-20" for the fumigation of imported seeds. For example, larvae of Megastigmus are highly tolerant to methyl bromide at dosages which will not cause severe loss of seed germinative ability (87). No other fumigants are registered for this use.

E. Exposure Hazards

No definitive information is available to document the number of individuals involved in the fumigation of grain or the amount of time devoted to such activity. As previously noted in the Section "Use of CCl_4 in On-Farm Grain Storage," less than 10 percent of the farmers surveyed reported that they fumigated their grain during periods of storage from 1 to 4 years. Furthermore, when they did fumigate, fumigants containing CCl_4 were used less than half of the time in the two principal commodities stored, wheat and corn. The relatively infrequent use of fumigants in farm storage was also reported by Harein, et al. (46) who estimated that only 2.8 percent of the corn farmers and 8.2 percent of the wheat farmers in Minnesota fumigated grain stored on their farms.

An estimate of the potential number of farmers involved in fumigation with CCl_4 -based liquid fumigants is obtained by first adding the total number of farmers^s reported in the 15 States that store over 90 percent of the grain on the farm (115):

State	Number of Farms
Colorado	26,500
Idaho	24,200
Illinois	105,000
Indiana	87,000
Iowa	118,000
Kansas	74,000
Michigan	65,000
Minnesota	105,000
Missouri	119,000
Montana	23,900
Nebraska	64,000
North Dakota	40,000
Ohio	94,000
South Dakota	38,000
Wisconsin	93,000

Next, assume that between 5 and 10 percent of those farms would have one person per farm engaged in fumigating grain, but with only half of this total or 2-1/2 to 5 percent using CCl_4 -based fumigants. It follows that 2-1/2 to 5 percent of the approximately 1 million individuals from the total number of farms in the 15 states that store most of the grain might be directly involved with the application of CCl_4 liquid fumigant materials. This amounts to between 25,000 to 50,000 farmers. The total U.S. farm population listed for 1980 is 6,051,000 and the national population is 222,167,000 (115). Therefore, the estimated number of farmers possibly involved in the application of grain fumigants containing CCl_4 represents between 0.4 percent and 0.8 percent of the total farm population and between 0.01 percent and 0.02 percent of the national population. The number of farmers applying liquid fumigants would be further reduced by subtracting those farmers who report their grain as fumigated, but have the treatments done commercially.

In the most recent UDSA Farm Bulletin on controlling insects in farm stored grain (101), farmers were asked to consider the following five factors before deciding whether to hire the services of a professional fumigant applicator or to do the fumigating themselves:

1. Their knowledge of and experience in fumigating.
2. The high cost of fumigants when purchased in small quantities.
3. The special equipment required to apply fumigants.
4. The need for safety devices such as gas masks necessary to prevent exposure to fumigants.
5. The personal risk.

A recent Nebraska bulletin on Farm Grain Fumigation (82) advises the farmer to consider hiring a professional fumigator, if quantities of over 10,000

bushels need to be fumigated. The reasons were based primarily on less cost per bushel for commercial treatment than for do-it-yourself treatments when the expenses for safety devices, application equipment, and personal time and labor are added to the cost of the fumigant.

Current fumigation bulletins or pamphlets, whether of state, federal, or industrial origin, present the reader with information concerning regulations that govern pesticide use. Although most chemical compounds used in liquid fumigant mixtures are not technically placed in the "restricted use" classification at present, this distinction is generally ignored and the farmer is advised that training and certification is required to purchase and apply "restricted use" pesticides.

Data on fumigant use in commercial grain storage were developed in a limited series of spot checks completed in July 1981 (102). Elevator managers in Montana, Wyoming, Oregon, Indiana, and Kansas were asked to respond to the following questions:

1. Do you do the fumigation yourself or hire a commercial applicator?
2. If you do the fumigation yourself, how many employees are usually involved in the fumigation process and how much time is spent by each employee in this activity per year?

All responses to question #1 stated that elevator fumigations were performed by certified applicators in the employ of the elevator and not contracted out to commercial applicators. Responses to question #2 indicate that most elevator fumigations typically involve two people who spend an estimated 40 hours each per year in this activity.

Exposure risks in commercial elevators also extend to personnel who work in areas adjacent to points of fumigation or who must handle recently fumigated grain. Storey, and others (103) found that dust collection equipment

effectively removed concentrations of a fumigant mixture composed of carbon tetrachloride and carbon disulfide in grain handling equipment during transfers of recently fumigated grain, but did not in all cases reduce the concentrations to accepted safe levels for repeated or prolonged exposure. To address the problem of passive exposure, the National Fire Protection Association's Advisory Guide NFPAG 61-B (9) recommends an inspection during the fumigation process using approved fumigant detecting equipment to determine if leaks are present that may constitute a hazard to persons occupying adjacent spaces. Special ventilation procedures were also recommended to ensure that work spaces are kept free of fumigant vapor or held to or below permissible levels. The Guide further advises that no reentry into the fumigated area be permitted until the atmosphere has been tested and determined to be safe for occupancy.

The problems of fumigant exposure among grain elevator workers who applied fumigants or handled fumigated grain in past years were examined in a series of articles appearing in the Milwaukee Journal during the fall of 1978 (43). The articles recounted past abuses in fumigant use and the reported effect on individual workers. The authors concluded that while many of the questionable fumigation practices of the past had been discontinued, many problems still exist that threaten the health and safety of grain workers.

Problems related to failure to placard railcars fumigated after loading and to the improper treatment of grain after loading on trucks were discussed in a U.S. General Accounting Office (GAO) Report entitled "Grain Fumigation: A multifaceted issue needing coordinated attention" (121). Railcars and trucks arriving at port terminals in Duluth-Superior and in Portland, Oregon were frequently found to contain recently fumigated grain, but were not placarded with warnings that their loads were treated. As a result, it was reported that

"unsuspecting grain samplers, inspectors, and other workers were exposed to harmful fumigated levels." As an outgrowth of this problem, grain workers in the Duluth-Superior area obtained contract provisions that required testing of all incoming shipments and the setting aside of shipments that exceed prescribed levels of fumigant concentrations.

The GAO Report also noted the concern among some grain inspectors about exposure to grain fumigants during the "sniffing" of grain samples to detect objectionable odors. A research project is currently being conducted at the University of Minnesota to monitor CCl_4 air concentrations in the working area of grain graders and grain samplers. Within a few selected sites, the study has documented that personnel are periodically over-exposed to CCl_4 .

Exposure to CCl_4 -based grain fumigants appears to occur most often through inhalation of the fumigant vapors during the following actions:

1. Loading or transfer of the liquid from one container to another during preparations for fumigation.
2. Applying the liquid to the grain surface.
3. Transferring recently fumigated grain from incoming railcars and trucks or during loading of fumigated grain from elevators to transporting carriers.
4. Sampling and inspection of fumigated grain prior to aeration.
5. Reentering fumigated areas following treatment.

If direct contact with fumigant vapor cannot be avoided, the worker must be provided with adequate respiratory protection to either remove the toxic fumigant gas from the air he breathes (using such devices as a gas mask and cannister filled with material designed to filter out the fumigant vapors), he must be supplied with a source of clean uncontaminated air from a supplied air source, or he must be provided with a self-contained breathing apparatus.

Adoption of the following guidelines would reduce the hazards associated with the use of CCl_4 -based liquid grain fumigants:

1. Classify CCl_4 and the other fumigant compounds used in mixtures with CCl_4 as "restricted use" pesticides.
2. If authority to purchase and apply CCl_4 -based fumigants cannot be legally or practically limited to professional applicators only, steps should be taken to ensure that training on fumigant use is included in private applicator certification programs.
3. Standardize the recommendations (methods of application, dosage, warnings, temperature restrictions) on labels for fumigant mixtures of essentially the same formulation.
4. Promote application and distribution techniques that provide for "remote" application of liquid fumigants. Examples are: Mobile spray booms in flat storages, recirculation of fumigant vapor following application in overhead space through stationary nozzles.
5. Restrict the use of CCl_4 -based liquid fumigants when grain temperatures fall below 15°C (60°F). Labels that recommend application at grain temperatures above 60°F should prohibit applications below 60°F .
6. Require that protective respiratory gear be used whenever CCl_4 -based fumigants are exposed to air.
7. When fumigating in structures attached or adjacent to other work areas, an inspection should be required while the fumigation is in progress using fumigant detecting equipment to determine if leaks are present that may constitute a hazard. Similar checks should be made during degassing of fumigated grain.

8. Prohibit the intransit fumigation of bulk grain in trucks, railcars, and barges with liquid grain fumigants. If treatment is permitted in these transportation modes while stationary, exposures should not be less than 48 hours, followed by a sufficient period of aeration or ventilation to reduce gas concentrations to safe levels.
9. Require that fumigated areas be tested for safe occupancy before reentry is permitted.
10. Require that fumigated grain be properly aerated before it is examined by quality control personnel.

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APPENDIX I

Export Grain Elevators

<u>Name</u>	<u>Comment</u>
1. Bunge Grain Elevator River Road P.O. Box 156 Destrehan, LA 70047	Storage Capacity: 8.0 million bushels Loading Capacity (BU/HR): 80,000
2. Farmers Export P.O. Box 97 Ama, LA 70031	Storage Capacity: 5.0 million bushels Loading Capacity (BU/HR): 80,000
3. Garnae Grain Inc. & ADM Export Company St. Charles Grain Elevator P.O. Box 267 Destrehan, LA 70047	Storage Capacity: 5.2 million bushels Loading Capacity (BU/HR): 80,000
4. Cooper Stevedores, Inc. Bussco I (Floating Rig) Bulk Stevedore Service ITM Building New Orleans, LA 70130	Storage Capacity: Loading Capacity (BU/HR): 18,000
5. International Grain Transfer, Inc. Commit II (Floating Rig) Rogers Terminal & Shipping New Orleans, LA 70806	Storage Capacity: Loading Capacity (BU/HR): 12,000
6. Midstream Transfer Gemini (Floating Rig) P.O. Box 176 Destrehan, LA 70047	Storage Capacity: (2 blending bins) Loading Capacity (BU/HR): 40,000
7. Cooper Stevedores, Inc. RG-1 (Floating Rig) River Grain Elevators, Inc. 2030 ITM Building New Orleans, LA 70130	Storage Capacity: (1 blending bin) Loading Capacity (BU/HR): 12,000
8. Continental Grain Co. P.O. Box 1531 Lake Charles, LA 70602	Storage Capacity: 0.6 million bushels Loading Capacity (BU/HR): 25,000
9. American Grain Related Industries Paktank Bulk Services P.O. Box 2422 Sulphur, LA 70663	Storage Capacity: 0.95 million bushels Loading Capacity (BU/HR): 40,000

NameComment

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|---|--|
| 10. Cargill Elevator
P.O. Box 200
Port Allen, LA 70767 | Storage Capacity: 7.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 11. Cargill Elevator
P.O. Drawer AR
Reserve, LA 70084 | Storage Capacity: 7.743 million bushels
Loading Capacity (BU/HR): 100,000 |
| 12. Continntal Elevator
P.O. Drawer AC
Reserve, LA 70084 | Storage Capacity: 3.6 million bushels
Loading Capacity (BU/HR): 80,000 |
| 13. Peavey Grain Elevator
General Delivery
Paulina, LA 70763 | Storage Capacity: 2.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 14. Atlantic Gulf Stevedores
Margaret G (Floating Rig)
Route 1
P.O. Box 535
Paulina, LA 70763 | Storage Capacity:
Loading Capacity (BU/HR): 300 tons/hr |
| 15. Delta Bulk Terminal
Delta Conveyor
(Floating Elevator)
Convent, LA | Storage Capacity:
Loading Capacity (BU/HR): 50,000 |
| 16. Louis Dreyfus Corporation
Jackson County
Terminal Elevator
P.O. Box 938
Pascagoula, Miss. 39567 | Storage Capacity; 3.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 17. State of Alabama
Public Grain Elevator
Pier D, South
P.O. Box 1588
Mobile, Ala. 33601 | Storage Capacity: 3.3 million bushels
Loading Capacity (BU/HR): 40,000 |
| 18. Continental Grain Company
Savannah State Dock Elevator
Georgia Port Authority
Port Wentworth
Savannah, GA 31402 | Storage Capacity: 1.5 million bushels
Loading Capacity (BU/HR): 30,000 |
| 19. S. C. Farm Bureau
S. C. Marketing Association
P.O. Box 5785
N. Charleston, S.C. 29406 | Storage Capacity: 1.8 million bushels
Loading Capacity (BU/HR): 25,000 |

NameComment

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| 20. Continental Grain Elevator
P.O. Box 70
Westwego, La. 70094 | Storage Capacity:
Loading Capacity (BU/HR): 60,000 |
| 21. Ditta Feruzzi Serafino & Co.
Mississippi River
Grain Elevator
P.O. Box N
Belle Chase, LA 70037 | Storage Capacity: 6.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 22. Ryan-Walsh Stevedoring Co., Inc.
Market Street Wharf
1701 Tchoupitoulas Street
New Orleans, LA 70130 | Storage Capacity: (5,000 M.T. approx.)
Loading Capacity (BU/HR): N/A |
| 23. Pike Grain Co., Peavy Co.
& C. B. Fox Co.
Public Grain Elevator
Nashville Avenue Wharf
New Orleans, LA 70115 | Storage Capacity: 7.2 million bushels
Loading Capacity (BU/HR): 100,000 |
| 24. Dockside Elevator, Inc.
Mr. Bert (Floating Rig)
P.O. Box 52461
1421 South Peters
New Orleans, LA 70152 | Storage Capacity:
Loading Capacity (BU/HR): 10,000-15,000 |
| 25. Dockside Elevator, Inc.
LST (Floating Rig)
P.O. Box 52461
1421 South Peters
New Orleans, LA 70152 | Storage Capacity:
Loading Capacity (BU/HR): 15,000-20,000 |
| 26. Cargill, Inc.
Port of Albany
Albany, N.Y. 12202 | Storage Capacity: 10.9 million bushels
Loading Capacity (BU/HR): 50,000 |
| 27. Central Soya Company, Inc.
Canton Grain Elevator
Newkirk and Newgate Streets
Baltimore, Md. 21224 | Storage Capacity: 3.5 million bushels
Loading Capacity (BU/HR): 60,000 |
| 28. Indiana Grain Corp.
Locust Point Grain Elevator
Andre and Beason Streets
Baltimore, Md. 21230 | Storage Capacity: 3.8 million bushels
Loading Capacity (BU/HR): 36,000 |
| 29. Louis Dreyfus Corporation
Port Covington Elevator
Pier II
Port Covington Terminal
Baltimore, MD 21230 | Storage Capacity: 5.0 million bushels
Loading Capacity (BU/HR): 60,000 |

NameComment

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| 30. | Cargill Elevator
102nd & Torrence
Chicago, Ill. 60617 | Storage Capacity: 23.0 million bushels
Loading Capacity (BU/HR): 60,000
Number of legs in house: 9 |
| 31. | Continental Grain Company
Continental "B"
107th & Torrence
Chicago, Ill. 60617 | Storage Capacity: 10.5 million bushels
Loading Capacity (BU/HR): 30,000 |
| 32. | Continental Grain Company
Continental "C"
12700 Lake Calumet Drive
Chicago, IL 60633 | Storage Capacity: 6.5 million bushels
Loading Capacity (BU/HR): 40,000 |
| 33. | Cargill, Inc.
Elevator "E"
335 Muskego
Milwaukee, Wis. 53233 | Storage Capacity: 2.5 million bushels
Loading Capacity (BU/HR): 24,000 |
| 34. | Continental Grain Company
Elevator "K"
960 East Bay Street
Milwaukee, Wis. 53207 | Storage Capacity: 3.5 million bushels
Loading Capacity (BU/HR): 40,000 |
| 35. | Indian Grain Company
Gateway Elevator
12700 Butler Drive
Chicago, IL 60633 | Storage Capacity: 7.5 million bushels
Loading Capacity (BU/HR): 90,000 |
| 36. | General Mills
Rialto Elevator
10459 S. Muskegan Avenue
Chicago, IL 60604 | Storage Capacity: 3.0 million bushels
Loading Capacity (BU/HR): 40,000 |
| 37. | ADM Elevator "S"
St. Louis Bay
Superior, WI 54880 | Storage Capacity: 12.5 million bushels
Loading Capacity (BU/HR): 60,000 |
| 38. | Cargill, "B"
600 Garfield Avenue
P.O. Box 459
Duluth, Minn. 55802 | Storage Capacity: 8.5 million bushels
Loading Capacity (BU/HR): 140,000
(2 docks) |
| 39. | Cargill, "C"
600 Garfield Avenue
P.O. Box 459
Duluth, Minn. 55802 | Storage Capacity: 4.5 million bushels
Loading Capacity (BU/HR): 50,000 |
| 40. | Continental Elevator
P.O. Box 625
400 N. Main Street
Superior, WI 54880 | Storage Capacity: 5.0 million bushels
Loading Capacity (BU/HR): 75,000 |

NameComment

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|---|---|
| 41. General Mills
Elevator "A"
200 Garfield Avenue
Duluth, Minn. 55802 | Storage Capacity: 2.5 million bushels
Loading Capacity (BU/HR): 60,000 |
| 42. ConAgra, Inc.
Elevator "M"
Port of 200th Avenue, E.
Superior, Wis. 54880 | Storage Capacity: 2.5 million bushels
Loading Capacity (BU/HR): 19,000 (with
sampler); 47,000 (without sampler) |
| 43. Farmers Union Grain
Terminal Association
Farmers Union Elevator 1
41 Dock street
Superior, Wis. 54880 | Storage Capacity: 7.5 million bushels
Loading Capacity (BU/HR): 65,000 |
| 44. Farmers Union Grain
Terminal Association
Farmers Union Elevator 2
41 Dock Street
Superior, Wis. 54880 | Storage Capacity: 11.0 million bushels
Loading Capacity (BU/HR): 65,000 |
| 45. Farmers Union Grain
Terminal Association
Farmers Union 3
20 Dock
Superior, Wis. 54880 | Storage Capacity:
Loading Capacity (BU/HR): No loading
facility |
| 46. Peavey Company
Globe Elevator
St. Louis Bay
Superior, Wis. 54880 | Storage Capacity: 4.0 million bushels
Loading Capacity (BU/HR): 50,000 |
| 47. International Multi Foods
600 Garfield Avenue
Duluth, Minn. 55802 | Storage Capacity: 4.2 million bushels
Loading Capacity (BU/HR): 50,000 |
| 48. Cargill Elevator
P.O. Box 7506
Chesapeake, Va. 23324 | Storage Capacity: 6.8 million bushels
Loading Capacity (BU/HR): 70,000 |
| 49. Continental Grain Company
N & W Elevator
8900 Block Hampton Boulevard
Norfolk, VA 23514 | Storage Capacity: 3.5 million bushels
Loading Capacity (BU/HR): 50,000 |
| 50. Tidewater Grain Company
Girard Point, Pier 3
26th & Penrose Avenue
Philadelphia, Pa. 19145 | Storage Capacity: 2.25 million bushels
Loading Capacity (BU/HR): 60,000 |

NameComment

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| 51. Farmer's Export Company
Port Richmond Elevator
2870 East Allegheny Avenue
Philadelphia, Penn. 19134 | Storage Capacity: 3.5 million bushels
Loading Capacity (BU/HR): 60,000/hr |
| 52. Michigan Elevator Exchange
Division of Farm Bureau Services
P.O. Box 265
Carrollton, Mich. 48724 | Storage Capacity: 2.0 million bushels
Loading Capacity (BU/HR): 20,000 |
| 53. Wickes Agriculture
P.O. Box 487
Carrollton, Mich. 48724 | Storage Capacity: 2.7 million bushels
Loading Capacity (BU/HR): 20,000 |
| 54. Cargill-Toledo Elevator
125 Edwin Drive
Toledo, Ohio 43609 | Storage Capacity: 4.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 55. The Andersons
Anderson River
P.O. Box 119
Maumee, Ohio 43537 | Storage Capacity: 7.0 million bushels
Loading Capacity (BU/HR): 50,000 |
| 56. Cargill Inc.
Cargill River "E"
901 Miami Street
Toledo, Ohio 43605 | Storage Capacity: 1.6 million bushels
Loading Capacity (BU/HR): 45,000 |
| 57. Mid-States Terminals, Inc.
Mid-States Elevator
P.O. Box 357, Main Office
Toledo, Ohio 43691 | Storage Capacity: 6.0 million bushels
Loading Capacity (BU/HR): 45,000 |
| 58. The Pillsbury Company
P.O. Box 458
Huron, Ohio 44839 | Storage Capacity: 1.75 million bushels
Loading Capacity (BU/HR): 15,000 |
| 59. Public Elevator
Bunge Corporation
P.O. Box 690
Galveston, Tex. 77550 | Storage Capacity: 8.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 60. Farmers Export Elevator
P.O. Box 2647
Galveston, Tex. 77550 | Storage Capacity: 2.8 million bushels
Loading Capacity (BU/HR): 120,000 |
| 61. Houston Public Grain Elevator
8400 Block, Clinton Drive
P.O. Box 2562
Houston, Tex. 77001 | Storage Capacity: 6.0 million bushels
Loading Capacity (BU/HR): 75,000 |

NameComment

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| 62. Continental Grain Company
Beaumont Elevator
P.O. Box 1631
Beaumont, Tex. 77704 | Storage Capacity: 3.5 million bushels
Loading Capacity (BU/HR): 50,000 |
| 63. Cargill Elevator
P.O. Box 1117
Port Arthur, Tex. 77640 | Storage Capacity: 3.7 million bushels
Loading Capacity (BU/HR): 40,000 |
| 64. Cargill, Inc.
14910 Market Street
P.O. Box 220
Channelview, Tex. 77530 | Storage Capacity: 6.0 million bushels
Loading Capacity (BU/HR): 190,000 |
| 65. Union Export Coop. Ex.
Equity Export Elevator
2631 Tidal Road
P.O. Box 68
Deer Park, Tex. 77536 | Storage Capacity: 8.5 million bushels
Loading Capacity (BU/HR): 120,000 |
| 66. Agri Industries
Agri Export
1606 Clinton Drive
P.O. Box 406
Galena Park, Tex. 77547 | Storage Capacity: 6.4 million bushels
Loading Capacity (BU/HR): 115,000 |
| 67. Brownsville Navigation District
Port of Brownsville
Public Elevator
P.O. Drawer 3070
Brownsville, Tex. 78520 | Storage Capacity: 3.0 million bushels
Loading Capacity (BU/HR): 40,000 |
| 68. Corpus Christi Navigator
District
Corpus Christi Public Elevator
P.O. Box 2229
Corpus Christi, Tex. 78403 | Storage Capacity: 5.0 million bushels
Loading Capacity (BU/HR): 100,000 |
| 69. Producers Grain Corporation
Producers Grain Port Terminal
P.O. Box 5407
Corpus Christi, Tex. 78405 | Storage Capacity: 6.3 million bushels
Loading Capacity (BU/HR): 40,000 |
| 70. Cargill, Inc.
Cargill Terminal #4
Foot of North Burgard Street
Portland, oreg. 97203 | Storage Capacity: 8.0 million bushels
Loading Capacity (BU/HR): 99,000 |
| 71. Continental Grain Company
P.O. Box 887
Longview, Wash. 98632 | Storage Capacity: 5.0 million bushels
Loading Capacity (BU/HR): 30,000 |

NameComment

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|---|--|
| 72. Louis Dreyfus Corporation
Foot of Holladay Street
Portland, Oreg. 97232 | Storage Capacity: 1.8 million bushels
Loading Capacity (BU/HR): 45,000 |
| 73. Columbia Grain, Inc.
Terminal #5
Suite 1010
200 S. W. Market Street
Portland, Oreg. 97201 | Storage Capacity: 1.5 million bushels
Loading Capacity (BU/HR): 70,000 |
| 74. United Grain Corporation
P.O. Box 1828
Arnada Annex
Vancouver, WA 98660 | Storage Capacity: 4.5 million bushels
Loading Capacity (BU/HR): 60,000 |
| 75. Bunge Grain Corporation
Portland Grain Terminal
800 N. River
Portland, Oreg. 97227 | Storage Capacity: 1.5 million bushels
Loading Capacity (BU/HR): 40,000 |
| 76. N. Pacific Grain Growers, Inc.
N. Pacific Grain Growers
Elevator
P.O. Box 38
Kalama, Wash. 98625 | Storage Capacity: 4.0 million bushels
Loading Capacity (BU/HR): 60,000 |
| 77. Stockton-Continental Elevators
Port of San Francisco
Grain Terminal, Pier 90
3301 3rd Street
Pier 90
San Francisco, Calif. 94124 | Storage Capacity: 2.0 million bushels
Loading Capacity (BU/HR): 50,000 |
| 78. Stockton-Continental Elevator
1805 Harbor Road
Stockton, Calif. 95201 | Storage Capacity: 6.5 million bushels
Loading Capacity (BU/HR): 40,000 |
| 79. Cargill California, Inc.
Cargill Elevator, Sacramento
Yolo Port District
P.O. Box 774
west Sacramento, Calif. 95691 | Storage Capacity: 1.25 million bushels
Loading Capacity (BU/HR): 21,200 |
| 80. Koppell Bulk (Terminal)
1130 panorama Drive
Long Beach, Calif. 90801 | Storage Capacity: 2.25 million bushels
Loading Capacity (BU/HR): 60,000 |
| 81. Garnac Grain, Inc.
San Diego Public Bulk Terminal
1090 Water Street
San Diego, Calif. 92101 | Storage Capacity: 0.5 million bushels
Loading Capacity (BU/HR): 36,666 |

NameComment

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| 82. Cargill Elevator - Pier 86
955 Alaskan Way West
Seattle, WA 98119 | Storage Capacity: 0.5 million bushels
Loading Capacity (BU/HR): 100,000
(3,000 tons/hr.) |
| 83. Continental Elevator Company
11 Shuster Drive
Tacoma, Wash. 98119 | Storage Capacity: 3.2 million bushels
Loading Capacity (BU/HR): 60,000
(1,800 tons/hr.) |
| 84. United Grain Corporation
United Grain Elevator
559 Port of Tacoma Road
Tacoma, Wash. 98412 | Storage Capacity: 4.1 million bushels
Loading Capacity (BU/HR): 30,000
(900 tons/hr.) |

APPENDIX II

Ships Fumigated for Cargill, Inc., Norfolk, Va.

	<u>Date</u>	<u>Ship Fumigated</u>	<u>Holds Fumigated</u>	<u>Fumigant Used</u>	<u>Destination</u>
1.	10-18-78	REBECCA	6	Weevil-Cide	Netherlands
2.	11-9-78	SAC MALAGA	1,5	Weevil-Cide	Spain
3.	2-11-79	SOLEDAD MARIA	2	Weevil-Cide	Spain
4.	6-11-79	TOYOTO MARU #14	1	Weevil-Cide	Japan
5.	7-11-79	M. S. SLIEDRECHT	1	Weevil-Cide	Ghent
6.	7-17-79	MEXICAN GULF	7	Phosphine	Poland
7.	7-19-79	BENIGNITY	1,2,4,5	Phosphine	PRC
8.	7-22-79	M/V MULHEIM	1,2,3,4,5,6,7	Phosphine	PRC
9.	8-23-79	MARCOVERDE	2	Phosphine	Spain
10.	8-23-79	TASMAN SEA	1,2,3,4,5,6,7,8,9	Phosphine	PRC
11.	8-27-79	JONNI	1,2,3,4,5,6,7	Phosphine	PRC
12.	9-12-79	MARILYN L	1,2,3,4,5,6	Phosphine	PRC
13.	9-15-79	JALAVIHAR	6	Phosphine	Ghent
14.	10-16-79	M/V SAC MALAGA	2,3,7	Phosphine	Spain
15.	10-26-79	OCEAN FRIEND	4	Phosphine	Iran
16.	11-14-79	DAY SPRING	1,2,3,4,5,6	Phosphine	PRC
17.	11-17-79	M/V AJANTA	3,5	Phosphine	France
18.	1-10-80	M/V AIBOA	5	Phosphine	Spain
19.	2-2-80	SEINE MARU	1,2,3,4,5	Phosphine	PRC
20.	2-10-80	FRUITION	1,2,5,6,7	Phosphine	PRC
21.	3-11-80	KORO SEA	1,2,3,4	Phosphine	PRC
22.	4-3-80	M/V DRAKE SEA	1,2,3,5,6,7	Phosphine	PRC
23.	4-5-80	M/V FLISVOS	1,2,3,4,5,6,7	Phosphine	PRC
		Wing Tanks	2,3,4,5,6		

Ships Fumigated for Tidewater Grain Co., Philadelphia, Pa.

	<u>Date</u>	<u>Ship Fumigated</u>	<u>Holds Fumigated</u>	<u>Fumigant Used</u>
24.	8-28-79	M/V MALAGA	7	Phosphine
25.	9-4-79	KUMANOVO	3,6	Phosphine
26.	9-26-79	STALO 2	2,6	Phosphine
27.	10-5-79	M/V NEREO	2	Phosphine
28.	10-19-79	M/V XAPETAN RAHIOTIS	1,2,5,6	Phosphine

Ships Fumigated for Farmers Export Co., Philadelphia, Pa.

	<u>Date</u>	<u>Ship Fumigated</u>	<u>Holds Fumigated</u>	<u>Fumigant Used</u>
29.	9-7-79	M/V OCEAN FRIEND	1,2,3,4,5	Phosphine
30.	10-2-79	M/V TAI CORN	2	Phosphine
31.	10-23-79	M/V RIO LINDO	1,2,3,4,5,6,7	Phosphine
32.	12-27-79	M/V NOVA GARICA	1,2,3,4,5	Phosphine
33.	1-12-80	IRISH LARCH	1,2,4,5	Phosphine

Ships Fumigated for Cargill, Inc.

	<u>Date</u>	<u>Vessel</u>	<u>Flag</u>	<u>Destination</u>	<u>Quan. Mt.</u>	<u>Ex. Elev.</u>	<u>Grain</u>
1.	9/4/79	Fontini L.	Greece	PRC*	40,642	Tacoma	Corn
3.	9/13/79	Fontini L.	Greece	PRC	17,499	P-86	Corn
6.	9/22/79	On Lee	Panama	PRC	34,502	P-86	Corn
7.	10/12/79	Mulheim	Panama	PRC	34,875	P-86	Corn
8.	12/8/79	Weedle Sea	Panama	PRC	32,158	T-4	SW Wheat
9.	1/15/80	Honesty	Panama	PRC	21,359	P-86	Corn
0.	1/15/80	Devotion	Panama	PRC	12,259	P-86	Corn
1.	1/17/80	Devotion	Panama	PRC	30,481	Tacoma	Corn
2.	1/25/80	Saltness	United Kingdom	PRC	19,732	P-86	Corn
3.	1/30/80	Weedle Sea	Panama	PRC	32,209	T-4	SW Wheat
4.	2/19/80	Caspian Sea	Panama	PRC	34,139	T-4	SW Wheat
5.	2/25/80	Bless River	liberia	PRC	8,034	Bunge	SW Wheat
6.	2/28/80	Bless River	Liberia	PRC	22,731	T-4	SW Wheat
7.	3/3/80	Diavolezza	Switzerland	PRC	30,000	Tacoma	Corn
8.	3/18/80	Humanist	United Kingdom	PRC	31,396	T-4	SW Wheat
9.	11/6/78	Atlantic Star	Greece	China	5,500	Duluth	Spring Wheat
50.	6/20/79	Alepo	Sweden	PRC	33,748	Sacramento	HRWW**
51.	6/24/79	Kyuko Maru	Japan	PRC	42,953	Sacramento	HRWW
52.	6/30/79	Kyrakatiugo	Greece	PRC	45,526	Sacramento	HRWW
53.	7/9/79	Unison	Panama	PRC	46,240	Sacramento	HRWW
54.	7/12/79	Stove Transport	Sweden	PRC	29,068	Sacramento	HRWW
55.	7/20/79	On Lee	Panama	PRC	39,413	Sacramento	HRWW
56.	7/25/79	Belstar	Norway	PRC	33,992	Sacramento	HRWW
57.	8/2/79	On Ding	Panama	PRC	35,525	Sacramento	HRWW
58.	8/6/79	Day Spring	Panama	PRC	22,843	Sacramento	HRWW
59.	8/16/79	Caspian Sea	Panama	PRC	37,777	Sacramento	HRWW
60.	10/11/79	Zhi Hai	PRC	PRC	26,019	Sacramento	HRWW
61.	2/1/79	Point Judy		Egypt	19,900	Albany	Wheat
62.	9/26/79	Prince Rupert City		Scotland	2,500	Albany	Yellow Corn

* PRC = People's Republic of China

** HHRW = Hard red winter wheat

Ships Fumigated by U.S. Distributors of Phostoxin®

	<u>Name of Vessel</u>	<u>Date</u>	<u>Commodity</u>	<u>Desination</u>	<u>Metric Tons</u>
63.	S. S. ZORINA	1-14-78	Barley	Taiwan	25,700
64.	EASTERN FUJI	2-22-78	Wheat	Japan	7,875
65.	SIMANDOU	2-28-78	Bagged soybean meal	Iraq	13,900
66.	MISENK	3-31-78	Bagged soybean meal	Iraq	20,000
67.	M/V SYMI	4-01-78	Sunflower seed	Mexico	7,510
68.	MARINA C	6-20-78	Corn	Brazil	30,000
69.	P. S. PALIOS	7-11-78	#3 Corn	Brazil	21,715
70.	LONDON VISCOUNT	7-13-78	Corn	Portugal	7,145
71.	MAJESTY	7-26-78	Corn	Japan	10,570
72.	EREDINE	7.28-78	Barley	Poland	13,750
73.	GENERAL PRADZYNSKI	8-08-78	Corn	Poland	13,750
74.	KAMISHIO MARU	8-08-78	Bulk yellow corn	Mexico	10,570
75.	HANS SACHS	8-15-78	Yellow corn	Greece	15,145
76.	MINERAL LUXEMBOURG	8-25-78	Soybean meal	Oso	10,000
77.	M. V. ISLAND MARINER	8-30-78	Safflower seed	So. Europe	13,095
78.	PRINCESS AURORA	8-30-78	Yellow corn	Brazil	23,145
79.	ALKMAN	9-01-78	Yellow corn	Brazil	13,750
80.	M/V GEORGIANA	9-06-78	Corn	Dominican Rep.	4,000
81.	M/V WALCHAND	9-14-78	Soy pellets	Rotterdam	3,860
82.	SCOTSPARK	9-16-78	Wheat	--	3,430
83.	SILVER TRIDENT	9-21-78	Corn	--	8,570
84.	GOLDEN PANAGIA	9-21-78	Milo	Mexico	25,975
85.	E. R. SCALDIA	9-28-78	Corn	Poland	32,485
86.	M/A BIAKH	10-02-78	Corn	Trinidad	3,145
87.	M/V MARINE ELECTRIC	10-12-78	Wheat	Israel	8,570

Ships Fumigated by U.S. Distributors of Phostoxin® (Continued)

	<u>Name of Vessel</u>	<u>Date</u>	<u>Commodity</u>	<u>Desination</u>	<u>Metric Tons</u>
88.	NEW WESTMINISTER CITY	10-15-78	Corn	Brazil	23,600
89.	M/V OSTRIA	10-18-78	Corn	Brazil	25,145
90.	LIBERIAN STATESMAN	10-19-78	Corn	Brazil	26,710
91.	SANTA ELISABETTA	10-19-78	Corn	Egypt	22,285
92.	M/V WORLD NOBILITY	10-20-78	Corn	Brazil	25,430
93.	M/V CAPETAN RABIOTIS	10-22-78	Corn	Egypt	25,570
94.	TONGALA	10-23-78	Linseed meal, corn gluten pellets, wheat middle pellets; and soybean meal	Rotterdam	12,000
95.	M/V ALESSANDRA	10-30-78	Corn	Brazil	24,570
96.	M/V DOCEVEGA	11-03-78	Corn	Brazil	33,145
97.	M/ALBOU MARU	11-03-78	Corn	China	13,430
98.	M/FLOR	11-09-78	Corn Wheat	Egypt Portugal	13,715 4,570
99.	-----	11-10-78	Corn	Japan	14,285
100.	KOSMAJ	11-12-78	Corn	Yugoslavia	9,145
101.	M/V ANASTASIAS	11-13-78	Wheat	--	1,715
102.	FADURA	11-17-78	Soybean	Germany	4,570
103.	M/V LITA P. KURONEN	11-18-78	Corn	Brazil	29,430
104.	M/V HENNING OLDENDORFF	11-19-78	Corn	Brazil	30,000
105.	(Capt. Karl Haacker)	11-20-78	Corn	So. Korea	22,860
106.	CARLO M.	11-21-78	Corn	England	5,715
107.	(Capt. D. Vrakas)	11-22-78	Corn	China	27,430
108.	M/V GOLDEN PANAGIA	11-29-78	Corn	Mexico	18,570
109.	M/V KONKAR PIONEER	11-29-78	Corn	Brazil	35,049
110.	M/V CUMBRIA	11-30-78	Corn	Brazil	26,239

Ships Fumigated by U.S. Distributors of Phostoxin (Continued)

	<u>Name of Vessel</u>	<u>Date</u>	<u>Commodity</u>	<u>Desination</u>	<u>Metric Tons</u>
111.	M/V DIETRICH OLDENDORFF	12-01-78	Corn	Brazil	26,239
112.	M/V APOPOLOS ANDREAS	12-15-78	Corn	Brazil	27,996
113.	M/V JONNI	12-18-78	Corn	Brazil	26,671
114.	M/V ASTORIA	12-23,	Corn	Brazil	25,715
115.	M/V MATHIAS	1-21-79	Wheat	Venezuela	4,875
116.	M/V CAVALIER BULKER	3-20-79	Corn	Taiwan	6,285
117.	LIBERIAN M/S AL RAHIM	4-01-79	Wheat	Venezuela	7,143
118.	KIELDRECHT	5-03-79	--	--	20,280
119.	M/V SOLING	5-07-79	--	--	18,000
120.	M/V RIO VERDE	5-16-79	--	--	32,000
121.	ATLANTIC HERITAGE	5-23-79	Corn	Brazil	23,681
122.	OLYMPIC HOPE	5-31-79	--	--	22,217
123.	WILLIAMS	6-04-79	--	--	34,454
124.	STUDZIANSKI	6-22-79	Wheat	Polant	30,000
125.	GOLDEN NAGOS	6-29-79	#2 Yellow sorghum	Columbia	5,000
126.	M/V CORUPUNA	7-05-79	--	--	21,441
127.	M/V MANDARIN	7-05-79	Corn	Taiwan	6,950
128.	GENERAL DEM	7-09-79	--	--	34,741
129.	MIROSLAWIC	7-09-79	Wheat	Poland	31,000
130.	COROPUNG	7-12-79	Wheat	Polant	21,441
131.	MEXICAN GULF	7-12, 17-79	Barley	Poland or Mexico	21,166
132.	LIBERIAN M. S. ANNIE	7-21-79	Spring Wheat	Taiwan or Formosa	8,300
133.	NIWERSYTET	7-22-79	--	--	42,626
134.	CAPT. R. GRADZIK	7-26-79	Wheat	Poland	43,321

Ships Fumigated by U.S. Distributors of Phostoxin (Continued)

	<u>Name of Vessel</u>	<u>Date</u>	<u>Commodity</u>	<u>Desination</u>	<u>Metric Tons</u>
135.	M/V AZTECA	7-28-79	Wheat	No. Africa	7,143
136.	GEORGIS	7-31-79	--	--	6,700
137.	CAPETAN TASSOS	8-02-79	Corn	Romania	4,771
138.	M/V MARE PICENO	8-02-79	--	--	20,000
139.	MIROSLAWIC	8-02-79	--	Poland	29,453
140.	WALKANLODYCH	8-08-79	Corn	Poland	30,000
141.	M/V NOVAGORICA	8-12-79	Corn	Yugoslavia	25,000
142.	M/V BUDUA	8-14-79	#3 Yellow corn	Yugoslavia	26,000
143.	PINK SKY	8-15-79	--	--	30,000
144.	OCEAN GIRL	8-16-79	Wheat	Poland	45,714
145.	AGIOS NIKOLAS	8-16-79	#2 Yellow sorghum	Venezuela	26,000
146.	EASTERN RIVER LIBERIAN	8/16/79	Corn	Japan	7,440
147.	THEOSANO LIVANOS	8-20-79	Wheat	Tunisia	10,257
148.	M/V ELAFI	8-20-79	Wheat	Poland	32,609
149.	LUJUA	8-25-79	Corn	Spain	2,840
150.	TOXOTIS	8-30-79	Corn	Romania	7,430
151.	M/V GENERAL SWIERCZEWSKI	8-30-79	Corn	Poland	--
152.	DORIC ARROW	8-31-79	--	Venezuela	21,000
153.	M/V MAISTROS	9-01-79	#2 yellow sorghum	Poland	29,798
154.	M/V STUDZIANSKI	9-06-79	Wheat	Poland	34,000
155.	M/V OCEAN FRIEND	9-07-79	Wheat	Poland	--
156.	UNIWERSYTET JAGIEAONSKI	7-22-79	Wheat	Poland	42,625

Ships Fumigated by U.S. Distributors of Detia Gas®

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
157.	OGDEN FRAZER	7-24-78	5,588.30	--
158.	WORLD FINANCE	7-25-78	15,240.86	--
159.	29 EKIM	8-26-78	18,468.2482	--
160.	VINSTRA	8-31-78	21,224.8571	--
161.	JOHN LYRAS	9-6-78	12,658.4942	--
162.	NAI LUISA	9-7-78	7,384.782	Corn
163.	SIEKIERKI	9-9-78	7,514.6836	Corn
164.	JANA PRIYA	9-10-78	33,076.5031	Corn
165.	MAVIOS PATRIOT	9-11-78	9,197.7655	Corn
166.	HELEN	9-12-78	33,066.8326	Wheat
167.	YAFFA	9-14-78	46,583.2153	Wheat
168.	ANDROS TRANSPORT	9-15-78	4,446.0	Corn
169.	ARAD	9-15-78	9,280.5951	--
170.	SANTO DOMINGO	9-15-78	3,302.1863	Corn
171.	DIAMANTIS	9-15/16-78	61,978,4269	Wheat
172.	MENALON	9-16-78	2,090.2193	Corn
173.	STRASSBURG	9-17-78	33,076.5264	Corn
174.	ESSI CAMILLA	9-18-78	10,944.2778	Soybeans
175.	NORDHOLM	9-20-78	4,817.20	Wheat
176.	VENETIA	9-20-78	8,576.6034	Wheat
177.	NORDHOLM	9-22-78	--	Bagged flour
178.	GARTHNEWDD	9-23-78	35,033.978	Wheat
179.	CHIEFTAN BULKER	9-24-78	13,826.508	Corn
180.	MINI SAKURA	9-25-78	1,270.0716	Corn
181.	AOELIAN SKY	9-25-78	10,023.3148	Soybeans

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
182.	SIDNEY SPIRO	9-27-78	54,947.3646	Corn
183.	TITAN	9-28-78	9,457.46	Corn
184.	RIMBA SEPETIR	10-07-78	13,619.2579	Corn
185.	ERRADALE	10-12-78	23,463.812	Corn
186.	ATLANTICA	10-13-78	10,767.15	Wheat
187.	RIO HAINA	10-15-78	9,525.5375	Wheat
188.	HOHKOKUSAN MARU	10-17-78	24,632.2779	Corn
189.	IRENE PATERAS	10-23-78	26,250.7379	Corn
190.	NENA	10-25-78	17,781.003	Corn
191.	PENTALON	10-25-78	15,383.117	Wheat
192.	GOLDEN SABRE	11-01-78	27,263.8664	Corn
193.	LEROS	11-02-78	17,722.07	Corn
194.	ALEXANDER VENTURE	11-08-78	12,492.06	Wheat
195.	MASTER PETROS	11-16-78	16,297,5596	Corn
196.	MASTER PETROS	11-16-78	20,033.196	Corn
197.	CONSTANCE	11-17-78	9,874.0451	Corn
198.	ALEKOS	11-18-78	6,502,7306	Wheat
199.	HYDROHOS	11-19-78	30,872.8807	Corn
200.	ALOITH	11-19-78	10,866.73	Corn
201.	KONKAR RESOLUTE	11-19-78	34,485.3415	Corn
202.	GRECIAN TEMPLE	11-19-78	27,550.3288	Soybeans
203.	SPRAY CAP	11-20-78	6,069.1281	Wheat
204.	ELISA F.	11-22-78	12,097,1786	Corn
205.	EASTERN JADE	11-28-78	23-882.783	Corn
206.	ORFEO	11-28-78	6,600.00	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
207.	ORIENTAL FORREST	12-02-78	27,551.16	Soybeans
208.	MARIA	12-06-78	--	Bagged flour
209.	MASSIMILIAND F.	12-08-78	12,247.928	Soybeans
210.	GUDRID	12-19-78	--	Sacked flour
211.	MARIAS PERANZA F.	12-22-78	13,042.765	Soybeans
212.	EJORDNES	12-27-78	--	Bagged flour
213.	MR. MICHAEL	12-29-78	41,719.56	Corn
214.	WEDDELL SEA	12-31-78	31,997.6059	Corn
215.	GEORGE EMBIRICOS	1-15-79	29,973.6212	Corn
216.	GOLDEN LAUREL	2-14-79	22,596.00	Corn
217.	CAPETAN COSTIS I	4-30-79	23,922.671	Soybeans
218.	CARIBEAN ACE	5-02-79	1,910.0304	Wheat
219.	THAIASSINI AVRA	5-15-79	15,541.6786	Corn
220.	POLYXENE G.	5-30-79	12,612.2105	Corn
221.	MINI LIONESS	6-15-79	1,447.25	Wheat
222.	ANASTASIA	6-26-79	3,262.8927	Corn
223.	HEINRICH ARNOLD SCHULTE	6-30/7-3-79	14,790.3495	Soybeans
224.	GOLDEN BLISS	7-13-79	30,901.5366	Soybeans
225.	EAGLES CLIFFE	7-16-79	3,479.9610	Corn
226.	CRUZIERO DO SUL	7-18-79	31,501.4326	Wheat
227.	POINT SUSAN	7-27-79	3,840.6577	Wheat
228.	AVIOS CHALLENGER	8-02-79	--	Wheat pellets Soybean hulls
229.	CALABRIA	8-03-79	7,843.8829	Corn
230.	MINI LIONESS	8-07-79	1,407.7403	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
231.	SEA BIRD	8-07-79	3,096.07	Wheat
232.	TAMESIS	8-08-79	40,192.7267	Corn
233.	GOLDEN RIO	8-13-79	33,001.5117	Corn
234.	DHALIT	8-17-79	4,463.3493	Wheat
235.	BENJA LUKA	8-21-79	4,280.8499	Corn
236.	FINN BEAVER	8-21-79	28,922.354	Corn
237.	WORLD NAVIGATOR	8-23-79	22,284.7762	Corn
238.	HOHKOKUSAN MARU	8-26-79	30,111.6454	Corn
239.	SUIKO MARU	8-28-79	--	Wheat
240.	ALCAZAR	9-1/4-79	23,323.8874	Corn
241.	NAROTTAM MORARJEE	9-07-79	32,846.4105	Corn
242.	NAROTTAM MORARJEE	9-07-79	6,001.6271	Corn
243.	MINI LENS	9-08-79	1,419.7805	Wheat
244.	ZEPHYROS II	9-10-79	31,499.910	Corn
245.	NEDROMA	9-10-79	20,085.9866	Wheat
246.	SIFNOS	9-11-79	5,479.4254	Wheat
247.	SUTJESKA	9-19-79	9,378.39	Wheat and corn
248.	KORDUN	9-21-79	10,048.277	Wheat
249.	MARTHA	9-21-79	21,280.02	Corn
250.	OCEAN GALAXY	9-24-79	11,210.079	Corn
251.	LJUBIJA	8-31-79	--	Corn
252.	MASTER PETROS	9-25-79	14,924.5686	Wheat
253.	ALIMAR	9-28-79	4,148.99	Wheat
254.	NAVIOS MARINER	9-29-79	8,215.49	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
255.	LAGO IZABAL	10-01-79	2,925.37	Wheat
256.	APHRODITE	10-04-79	31,040.574	Corn
257.	APHRODITE	10-04-79	10,499.935	Corn
258.	MAZADA	10-04-79	12,097.2149	Wheat
259.	DANIE	10-04-79	2,172.84	Wheat
260.	GOLDEN DOLPHIN	10-05-79	28,692.073	Corn
261.	DIMITRIS	10-06-79	2,961.77	Wheat
262.	SYRA	10-06-79	4,105.56	Corn
263.	PHOLEGANDROS	10-09-79	7,501.11	Wheat
264.	THEANTO A. S.	10-10-79	Sacked	Corn
265.	SOUTH BEAUTY	10-11-79	8,037.2573	Corn
266.	ITEL POLARIS	10-17-79	49,999.995	Corn
267.	ORIENT TRUST	10-18-79	12,417.2076	Wheat
268.	VASILIAS	10-19-79	25,803.388	Corn
269.	WORLD COURAGE	10-23-79	41,999.889	Corn
270.	VINSTRA	10-28-79	45,468.60	Corn
271.	GOLDEN RIO	10-30-79	33,495.1581	Corn
272.	CHESHIRE	9-15-79	25,942.0305	Corn
273.	FEDERAL SUMIDA	9-22-79	29,999.306	Corn
274.	CARICA	9-23-79	28,771.913	Corn
275.	VESTEROY	11-01-79	47,072.00	Corn
276.	ANDROS MENTOR	11-01-79	20,189.36	Wheat
277.	ZEPHYROS II	11-02-79	26,248.185	Corn
278.	FIDIAS	11-04-79	31,467.863	Corn
279.	JILL CORD	11-06-79	26,249.977	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
280.	ARROW CANE	11-06-79	4,860.93	Wheat
281.	EL CHAMPION	11-08-79	24,680.566	Soybeans
282.	SHUKO MARU	11-08-79	26,210.5429	Soybeans
283.	MARY STOVE	11-11-79	47,249.878	Corn
284.	GIANNIA N	11-17-79	31,499.991	Corn
285.	BENEDETTA F.	11-18-79	11,820.89	Corn
286.	GRAIN TRANSPORTER	11-18-79	1,055.05	Wheat
287.	RIRUCCIA	11-19-79	45,315.7647	Corn
288.	MINOS	12-07-79	26,166.905	Corn
289.	PANGEON	12-09-79	31,497.493	Corn
290.	WORLD ARES	12-12-79	28,349.980	Corn
291.	THORUNN	12-17-79	41,008.428	Corn
292.	BERKSHIRE	12-19-79	26,140.559	Corn
293.	FROTAVEGA	12-27-79	38,229.316	Corn
294.	M/V PATRICIA V	01-07-80	23,821.823	Corn
295.	AEGEAN LION	01-10-80	48,299.907	Corn
296.	NIPPOU MARU	01-12-80	29,745.310	Corn
297.	ELEONORA F.	01-12-80	9,672.41	Corn
298.	WILD CLOVER	01-12-80	25,201.297	Corn
299.	AQUA JOY	01-14-80	39,890.021	Corn
300.	AMSTELLAAN	02-02-80	29,872.088	Corn
301.	NAFTOPEROS	02-12-80	26,182.914	Soybeans
302.	SAVA	02-23-80	24,011.276	Corn
303.	KELO	02-28-80	25,449.550	--
304.	RED SKY	03-20-80	29,005.688	Soybeans

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
305.	UMBERTO D'AMATO	03-20-80	25,524,383	Corn
306.	STAR PERSEUS	03-18-80	23,988.624	Corn
307.	NOVA GORICA	03-16-80	29,999.985	Corn
308.	ADAMAN SEA	03-06-80	34,750.554	Soybeans
309.	TORRENT	10-17-78	38,610,188	Corn
310.	ROYAL EAGLE	10-26-78	38,604.45	Corn
311.	GOTHIC CHIEF	10-24-78	30,583.33	Corn
312.	GIANNIS N.	11-09-78	34,828.938	Corn
313.	HELLA GRIEG	11-03-78	45,152.548	Corn
314.	BENIGNITY	11-04-78	21,545.255	Corn
315.	FANCY RIVER	10-27-78	30,208.156	Corn
316.	BRAIN POWER	11-20-78	19,081.647	Corn
317.	ALEXANDER STAR	11-11-78	34,856.2088	Corn
318.	SPRAY DERRICK	11-13-78	40,850	Corn
319.	KYUKO MARU	12-03-78	37,993.119	Corn
320.	VIKARA	11-24-78	45,003.8	Corn
321.	FONTINI L.	11-21-78	58,601.021	Corn
322.	BLESS RIVER	12-08-78	30,500.151	Corn
323.	WORLD NEWS	12-01-78	35,345,488	Corn
324.	PANTAZIS L.	11-26-78	25,450.712	Corn
325.	PATRICIA L.	12-08-78	25,605.125	Corn
326.	TOXON	12-18-78	25,357.132	Corn
327.	JAGAT SAMRAT	12-18-78	47,002.819	Corn
328.	CATHERINE L.	12-14-78	25,452.136	Corn
329.	MARINA L.	2-02-79	31,194.8888	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
330.	CAPT. GEORGE L.	2-08-79	31,192.157	Corn
331.	SCAPWILL	1-07-79	32,156.402	Corn
332.	ALBION	3-09-79	24,533.2123	Corn
333.	WORLD AJAX	1-22-79	32,258.0001	Corn
334.	PANTAZIS L.	1-25-79	25,470-9.8014	Corn
335.	LEONIDAS Z. CAMBANIS	1-18-79	25,077.2879	Corn
336.	W. C. VanHORN	2-17-79	43,080.8320	Corn
337.	EIRYU MARU	2-10-79	28,874.99	Corn
338.	PATRICIA L.	2-07-79	25,524.5807	Corn
339.	MARITIME CHALLENGE	2-28-79	30,036.51	Corn
340.	BERING SEA	3-01-79	33,666.2977	Corn
341.	ALLIANCE	3-17-79	47,653.1751	Corn
342.	ALLEPO	3-28-79	30,634.0892	Corn
343.	SEA LIONET	3-22-79	34,018,408	Corn
344.	DIXIE	3-09-79	46,205.3547	Corn
345.	ANNITSA L.	3-17-79	31,094.0624	Corn
346.	MARILYN L.	4-01-79	24,045.1102	Corn
347.	HUMANIST	4-11-79	30,374.9841	Corn
348.	NAN FENG	2-13-79	31,517.4669	Corn
349.	SALVIA	4-19-79	36,796.1489	Corn
350.	AL TAHIR	6-11-79	31,505.7153	Corn
351.	CALEDONIA	5-15-79	45,163.749	Corn
352.	BLUE SKY	4-25-79	31,143.1348	Corn
353.	ALBION	5-24-79	24,342.9102	Corn
354.	IONIAN LEADER	5-17-79	31,062.96	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
355.	WILMONA	6-03-78	44,894	Wheat
356.	FLISVOS	5-18-78	33,273	Wheat
357.	GOULIAS	6-09-78	34,775	Wheat
358.	APJ KARAN	6-19-78	25,366	Wheat
359.	MENKAR	6-28-78	24,707	Wheat
360.	OGDEN EXPLORER	6-23-78	24,931	Wheat
361.	MAIR	6-20-78	33,219	Wheat
362.	ON YEUNG	7-18-78	34,009	Wheat
363.	NORBU	7-06-78	27,002	Wheat
364.	NORTH HAMPTONSHIRE	6-30-78	27,919	Wheat
365.	FANCY RIVER	7-12-78	31,600	Wheat
366.	UBERTY	7-22-78	20,795	Wheat
367.	SOL HOLT	7-30-78	33,847	Wheat
368.	HONEY RIVER	7-22-78	31,913	Wheat
369.	SEA LIONET	8-02-78	36,363	Wheat
370.	REGAL SABRE	7-31-78	22,881	Wheat
371.	SOYO MARU	8-15-78	27,436.67	Wheat
372.	GAREFOWL	8-03-78	29,326	Wheat
373.	NEW CORRAL SEA	7-31-78	16,505	Wheat
374.	DEXTERITY	8-03-78	20,544	Wheat
375.	TOYOTA MARU	8-07-78	28,442	Wheat
376.	SEA KITTIE	8-20-78	25,734.8	Wheat
377.	MARITIME INVESTOR	8-16-78	35,027.26	Wheat
378.	LOTUS	8-24-78	15,301.49	Wheat
379.	MARI CHANDRIS	9-03-78	31,700	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
380.	EAST PORT	9-06-78	37,523	Wheat
381.	NEW SULU SEA	9-18-78	18,299	Wheat
382.	ON LESS	9-25-78	34,119	Wheat
383.	LEONIDAS Z. CAMBANIS	9-02-78	26,065.8	Wheat
384.	THERMOPYLAI	9-24-7	823,878.12	Wheat
385.	MARATHON	9-16-78	18,433.85	Wheat
386.	CHENNAI OOKKEM	10-31-78	34,807	Wheat
387.	MARY STOVE	11-22-78	49,191.129	Wheat
388.	TACHIBANA	12-07-78	45,104.7619	Wheat
389.	POLY HYMNIA	11-16-78	39,996.9523	Wheat
390.	PILOT TRADER	11-10-78	40,942.5578	Wheat
391.	JARILLA	11-21-78	39,368.707	Wheat
392.	BARANJA	12-04-78	25,076	Wheat
393.	AMSTELWALL	11-30-78	33,444.3891	Wheat
394.	SILVRETTA	12-15-78	27,987.7006	Wheat
395.	NIKKO MARU	12-14-78	41,992.3809	Wheat
396.	GOLDEN KIMISIS	12-17-78	27,845.0612	Wheat
397.	UBERTY	10-17-78	20,795.96	Wheat
398.	SEA CALF	10-24-78	31,598	Wheat
399.	ON YEUNG	11-04-78	36,135.276	Wheat
400.	POTENZA	10-23-78	14,126.98	Wheat
401.	DIXIE	10-17-78	47,933	Wheat
402.	HONEY RIVER	10-22-78	31,944	Wheat
403.	ARTHUR STOVE	1-16-79	46,736.0183	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
404.	MARATHA MELODY	2-22-79	47,011.0134	Wheat
405.	ITEL PEGASUS	1-11-79	30,700.2721	Wheat
406.	UBERTY	2-28-79	20,655.3435	Wheat
407.	PILOT MERCHANT	3-14-79	40,784.4733	Wheat
408.	CAPETAN YANNIS	1-28-79	36,747.9128	Wheat
409.	MARITIME NOBLE	9-25-78	21,519.494	Wheat
410.	SILVA PLANA	9-26-78	30,476	Wheat
411.	TRANS-OCEANICA ELENA	10-11-78	24,346	Wheat
412.	MERAKLIS	10-08-78	41,488	Wheat
413.	OROTAVA	10-25-78	39,011.21	Wheat
414.	HONESTY	11-08-78	21,176	Wheat
415.	HELEN	11-18-78	45,003.156	Wheat
416.	NEW SULU SEA	12-27-78	18,397.709	Wheat
417.	GENTLE RIVER	12-15-78	30,499.723	Wheat
418.	TRADE LIGHT	11-25-78	35,663.252	Wheat
419.	ORUNDA	11-29-78	40,025.263	Wheat
420.	ANNITSA L.	12-27-78	30,984.1405	Wheat
421.	ORJEN	1-24-79	47,490.039	Wheat
422.	ATLANTIC HORIZON	1-17-79	26,880.096	Wheat
423.	BUNKO MARU	3-05-79	38,019.999	Wheat
424.	ENGIADINA	2-19-79	41,891.62	Wheat
425.	FRUITION	10-02-79	35,999.763	Corn
426.	NORWEGIAN SEA	10-09-79	32,656.465	Corn
427.	LIU LIN HAI	10-08-79	35,545.594	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
428.	ON YEUNG	11-19-79	34,575.206	Corn
429.	ON LEE	11-29-79	33,529.5513	Corn
430.	BERING SEA	11-28-79	33,626.6718	Corn
431.	OLYMPIC HARMONY	12-18-79	24,918.5529	Corn
432.	OLYMPIC PRICE	1-10-80	24,207.32	Corn
433.	CATHERINE L.	10-20-79	18,368.272	Soybeans
434.	SANKO LIGHT	10-26-79	29,487.323	Soybeans
435.	SUIKO MARU	10-27-79	29,341.978	Soybeans
436.	MEERDRECHT	11-18-79	41,999.879	Soybeans
437.	SANKO MAPLE	11-15-79	40-390-823	Soybeans
438.	ALEEPO	6-21-79	30,615.92	Wheat
439.	KYRAKTINGO	7-03-79	39,623.6335	Wheat
440.	KYUKO MARU	6-26-79	38,966.632	Wheat
441.	UNISON	7-13-79	41,948.3173	Wheat
442.	STOVE TRANSPORT	7-14-79	30,395.2323	Wheat
443.	SEA LIONET	7-14-79	35, 697.7049	Wheat
444.	KORO SEA	7-07-79	18,782.3636	Wheat
445.	BENINGNITY	7-19-79	20,999.9771	Wheat
446.	MULHEIM	7-22-79	33,462.9277	Wheat
447.	WOKO MARU	7-07-79	30,425.0673	Wheat
448.	FRUITION	7-19-79	40,940,6073	Wheat
449.	PATRICIA L.	7-20-79	25,015.1908	Wheat
450.	SEA DANIEL	7-20-79	25,942,5378	Wheat
451.	HONESTY	7-21-79	21,000.9682	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
452.	ON LEE	7-24-79	35,754.9982	Wheat
453.	ON DING	8-04-79	32,227.6413	Wheat
454.	VEL STAR	7-26-79	30,837.0676	Wheat
455.	WILD CLOVER	8-07-79	26,044.3661	Wheat
456.	PRACTICIAN	7-30-79	31,571.083	Wheat
457.	DAY SPRING	8-07-79	20,722.3717	Wheat
458.	CASPIAN SEA	8-17-79	10,712.2725	Wheat
459.	CASPIAN SEA	8-17-79	10,712.2725	Wheat
460.	PANGUEON	8-03-79	30,484.283	Wheat
461.	JONNI	8-27-79	27,006.8=7654	Wheat
462.	MARILYN L.	9-12-79	25,299.0262	Wheat
263.	AL TAWWAB	9-07-79	26,251.198	Wheat
264.	SEA CALF	9-26-79	31,522.9741	Wheat
465.	BERING SEA	9-05-79	34,451.2602	Wheat
466.	MARY LISA	8-26-79	24,320.6455	Wheat
467.	EASTERN HORNET	9-30-79	29,750.9383	Wheat
468.	WEDDEL SEA	10-02-79	32,201.2377	Wheat
469.	UNISON	9-23-79	41,997.0013	Wheat
470.	SEA DANIEL	10-13-79	25,330.9773	Wheat
471.	WEDDEL SEA	12-08-79	32,157.9241	Wheat
472.	ON DING	12-22-79	32,381.4181	Wheat
473.	SEINE MARU	2-02-80	32,967.8678	Wheat
474.	FRUITION	2-10-80	29,496.1550	Wheat
475.	KORO SEA	3-11-80	18,348.4482	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
476.	KARA	2-02-80	28,502.291	Wheat
477.	WEDDEL SEA	1-30-80	32,208.6902	Wheat
478.	CASPIAN SEA	2-19-80	34,139.1795	Wheat
479.	BLESS RIVER	2-28-80	30,764.578	Wheat
480.	DRAKE SEA	4-03-80	22,170.0686	Wheat
481.	HUMANIST	3-18-80	31,395.8526	Wheat
482.	FONTINI L.	9-13-79	58,140.6738	Corn
483.	ON LESS	9-22-79	34,501.9990	Corn
484.	KORO SEA	9-29-79	17,752.6815	Corn
485.	DRAKE SEA	10-16-79	22,047.9833	Corn
486.	NEW SULU SEA	10-16-79	17,521.8803	Corn
487.	ZHI HAI	10-13-79	23,754.98	Corn
488.	MULHEIM	10-12-79	34,875.2307	Corn
489.	OSTRIA TWO	11-16-79	33,378.8362	Corn
490.	CASPIAN SEA	11-30-79	33,833.1362	Corn
491.	THAMES MARU	12-04-79	33,268.7547	Corn
492.	ANDROS OCEANICA	12-10-79	33,967.141	Corn
493.	ANTIGUA	12-15-79	24,386.464	Corn
494.	SEA DANIEL	12-27-79	24,298.9593	Corn
495.	TORRENT	1-17-80	40,213.437	Corn
496.	DEVOTION	1-17-80	42,739.9721	Corn
497.	HONESTY	1-15-80	21,358.5691	Corn
498.	SALTNES	1-25-80	19,731.9731	Corn
499.	NORWEGIAN SEA	2-28-80	33,637.062	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
500.	DIAVOLEZZA	3-03-80	29,999.0714	Corn
501.	BUNKO MARU	3-16-80	42,499.9355	Corn
502.	ON YEUNG	3-24-80	33,957.829	Corn
503.	FLISVOS	4-05-80	32,695.3314	Corn
504.	DAY SPRING	11-14-79	20,610.0917	Soybeans
505.	CALORIC	11-15-79	48,192.0985	Soybeans
506.	WORLD CANDOR	2-13-80	24,092.543	Soybeans
507.	KYUKO MARU	3-03-80	39,564.5394	Soybeans
508.	TRAMONTANA	2-26-80	33,719.116	Soybeans
509.	ON DING	10-05-79	31,320.4134	Corn
510.	DEVOTION	11-10-79	42,353.1426	Corn
511.	TASMAN SEA	12-13-79	23,596.3401	Corn
512.	DAY SPRING	2-03-80	20,549.5916	Corn
513.	EKATERINI	3-24-80	41,992.3339	Corn
514.	NEW SULU SEA	2-29-80	17,781.0033	Wheat
515.	RONG CHENG	3-10-80	17,450,6164	Wheat
516.	DEVOTION	3-17-80	42,090.1893	Wheat
517.	GOULIAS	6-09-78	34,775.5	Wheat
518.	TARRENT	6-14-78	9,336.59	Wheat
519.	MARE PICENO	6-30-78	26,116.52	Wheat
520.	ANASTASIA	9-09-78	7,584.14	Wheat
521.	SPILIADA	9-21-78	20,986.70	Wheat
522.	BLIDNEN	6-14-78	20,884.54	Wheat
523.	DONNA SOPHIA	6-27-78	24,732.65	Wheat
524.	SOPHIA C	7-01-78	18,133.36	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

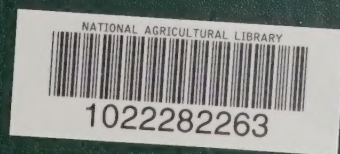
	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
525.	OGDEN SENEGAL	7-05-78	34,284.82	Wheat
526.	GOLDEN NAGOS	7-15-78	14,731.15	Wheat
527.	TELEVIV	7-19-78	12,564.27	Wheat
528.	GOLDEN POLYVINAMOS	7-22-78	24,761.90	Wheat
529.	ANASTASIA	7-29-78	3,350.34	Wheat
530.	MARINE ELECTRIC	8-05-78	25,122.88	Wheat
531.	ELAT	8-10-78	8,408.16	Wheat
532.	SOPHIA C	8-17-78	12,348.95	Wheat
533.	YCATIA HALCOUSSI	8-20-78	44,990.97	Wheat
534.	TOXOTIS	9-02-78	24,584.95	Wheat
535.	CHRISTINAI C	9-24-78	16,120.87	Wheat
536.	AEGIS KINGDOM	9-26-78	8,641.08	Wheat
537.	SOPHIA C	10-21-78	19,999.10	Wheat
538.	CHERRY	6-27-79	12,456.59	Wheat
539.	FELIKS DZIERZYNSAI	7-05-79	31,516.80	Wheat
540.	TOXOTIS	7-09-79	15,185.49	Wheat
541.	SPILIADA	7-27-79	7,987.80	Wheat
542.	JOANNA	8-06-79	32,183.97	Wheat
543.	TORN HILDE	8-14-79	38,564.38	Wheat
544.	TEX	8-21-79	4,402.72	Wheat
545.	COROPUNA	8-30-79	20,705.12	Wheat
546.	ANCHISIS	9-06-79	12,464.76	Wheat
547.	CHINA SEA	9-04-74	27,977,8644	Wheat
548.	BELOBO	8-21-74	54,132.26	Wheat and soybeans
549.	JARACONDA	8-18-74	46,266.89	Wheat

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
550.	ARETI	8-16-74	21,473.2831	Wheat
551.	OCEAN SKIPPER	8-11-74	32,615.44	Wheat
552.	SAVA	8-04-74	39,260.75	Wheat
553.	PHAEDRA	7-31-74	24,739.18	Wheat
554.	APPALLONIUS	7-31-74	25,349.11	Wheat
555.	PISTIS C	7-27-74	22,602.74	Wheat
556.	ARCHIMEDIS	7-27-74	25,691.74	Wheat
557.	ARCHIMEDIA	7-27-74	25,748.29	Wheat
558.	KAITY	7-23-74	37,013.52	Wheat
559.	FLORA N.	7-22-74	28,439.44	Wheat
560.	HECTOR	7-20-74	43,022.77	Wheat
561.	CARIBBEAN ARICHUNA	4-10-74	4,369.03	Wheat
562.	PELLEAS	4-07-74	13,810.76	Corn
563.	KIMON	3-29-74	4,702.70	Wheat
564.	ATLANTIC HERO	3-29-74	28,043.18	Corn
565.	ALEXANDROS T.	3-22-74	4,038.82	Wheat
566.	STALLO II	3-18-74	32,439.48	Corn
567.	SS TASMAN	3-16-74	25,198.22	Corn
568.	GERLIN	2-28-74	35,084.46	Corn
569.	JOANNA	2-14-74	20,999.86	Wheat
570.	PONDELIS S. LYRES	2-12-74	18,319.26	Corn
571.	AEGIS. KINGDOM	2-08-74	22,726.16	Wheat
572.	AQUA JOY	2-07-74	37,443.059	Corn
573.	THOMAS K.	1-31-74	19,894.41	Wheat
574.	AEGIS ELAND	1-28-74	19,305.08	Corn

Ships Fumigated by U.S. Distributors of Detia Gas® (Continued)

	<u>Name of Vessel</u>	<u>Date Fumigated</u>	<u>Metric Tons</u>	<u>Commodity</u>
575.	REYNOLDS	1-25-74	25,401.43	Corn
576.	WESTBULK	1-25-74	27,433.54	Corn
577.	STRYMON	1-23-74	27,433.54	Corn
578.	SCOTTS PARK	1-19-74	25,401.43	Corn
579.	SQUA FAITH	1-18-74	39,372.23	Wheat
580.	PANAGOS D. PATERAS	1-16-74	27,941.58	Wheat
581.	AMSTELHOFF	1-15-74	30,176.90	Wheat
582.	MERIGO YEMELOS	1-12-74	14,224.80	Corn
583.	SEAGULL	1-10-74	14,224.811	Wheat
584.	HAMBURGER WAPPEN	1-08-74	31,497.77	Corn
585.	AQUABELLE	1-07-74	38,406.96	Corn
586.	DICTO	1-02-74	20,463.39	Corn



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